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SNOWMELT FORECASTING - FURTHER COLD REGIONS DEVELOPMENT OF OPERATIONAL HYDROLOGICAL FORECASTING

Volume 2

by

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VOLUME 2

PREFACE

This volume contains all the information that is required to operate the computer simulation model SNOMO. The input files required, the operational logic of SNOMO and the output produced by SNOMO are discussed in detail. A full listing of the SNOMO Fortran-77 code is included.

CHAPTER 1: INPUT

1.1 Cell division.

The catchment is subdivided into computational units, called cells. The factors used for this subdivision are slope angle, aspect, elevation and vegetation cover type. The method for catchment subdivision is described in detail in chapter 5 (volume 1) and need not be repeated here. The catchment to be modelled will therefore consist of, after subdivision, a number of cells each with an aspect, slope angle, elevation and vegetation cover value. The location of each cell in the catchment is also known. The depth and occurrence of snowcover is calculated for each cell and the results for all the cells are examined together in order to calculate the snowcover depth and distribution over the whole catchment.

1.2 Input files.

The snowcover calculations are conducted separately for each cell. The presence of five data files (*snomo.dat*, *conif.dat*, *decid.dat*, *mix.dat* and *lapse.dat*) is required in order for SNOMO to operate correctly. The input required for these 5 files will be considered in detail below and has also been discussed in chapter 4 (volume 1).

1.2.1 *snomo.dat*.

Tables 1.1, 1.2 and 1.3 show sample *snomo.dat* files for cells 1 and 24 in 1988 and cell 1 in 1989 for the W3 catchment, Sleepers River Research Watershed, Danville, Vermont. Table 1.4 shows the variables contained in *snomo.dat*. The variables are considered in detail below in the order that they appear in the data file.

Table 1.1. Sample *snomo.dat* file for cell 1, W3, 1988.

```
1 1988
0.0 0.06 0.03 0.99 0.95 0.136
0.0 0.24 0.08 0.94 0.40 0.410
0.0 0.36 0.09 0.92 0.39 1.600
1010 5 100
6.15 -92.83 64 44.47
1
3
69.0
5.0
100.0 0.0 -1.0
39
64  1100 -11.1 -2.8 71.00 0.5 0.7 0.0
65  1100 -16.3 -5.8 36.00 0.5 4.2 0.2
66  1100 -16.6  0.0 31.00 0.5 1.7 0.0
67  1100 -6.0   5.6 46.00 0.7 2.5 1.5
68  1100 -14.0  4.4 32.00 0.0 1.7 0.1
69  1100 -1.9   4.6 55.00 1.0 1.8 6.1
70  1100 -7.8   2.4 75.00 0.5 3.1 1.6
71  1100 -15.3 -7.8 42.00 0.0 3.4 1.0
72  1100 -16.9 -1.6 37.00 0.5 2.0 0.0
73  1100 -3.8   3.6 80.00 0.5 1.1 4.8
74  1100 -5.9   0.3 77.00 1.0 1.9 1.4
75  1100 -6.2  -2.1 73.00 0.5 2.2 1.2
76  1100 -6.5   0.0 68.00 0.7 1.9 2.0
77  1100 -10.9  2.7 36.00 0.5 2.5 0.1
78  1100 -9.7   2.8 43.00 1.0 1.2 0.0
79  1100 -15.3  0.3 46.00 0.5 2.8 0.5
80  1100 -19.0 -6.1 67.00 0.5 2.5 2.8
81  1100 -22.7 -14.9 51.00 0.4 3.6 0.5
82  1100 -19.1 -4.2 46.00 0.5 2.8 0.0
83  1100 -15.4  4.8 32.00 0.4 2.7 0.0
84  1100 -0.3  11.0 65.00 0.5 1.2 0.0
85  1100 -0.4   7.2 61.00 0.5 1.4 0.0
86  1100  4.4   7.9 92.00 0.5 0.8 20.7
87  1100 -2.2   4.8 92.00 0.5 3.5 10.7
88  1100 -6.1  -0.2 78.00 0.5 2.1 1.2
89  1100 -8.0  12.7 43.00 0.5 1.1 0.0
90  1100  1.8  13.5 31.00 0.0 2.1 0.0
91  1100  0.3  10.8 60.00 0.0 2.1 0.0
92  1100  0.3  11.0 38.00 0.3 2.2 0.0
93  1100  1.1  16.8 47.00 0.5 1.4 0.0
94  1100  4.5   6.5 88.00 0.5 1.4 0.2
95  1100  3.3  11.6 95.00 1.0 0.5 0.4
96  1100  3.3   9.4 95.00 1.0 1.4 16.3
97  1100  0.9  15.3 74.00 0.6 1.0 0.0
```

continued overleaf...

47	98	1100	0.3	12.9	61.00	0.5	1.0	0.0
48	99	1100	3.4	6.9	87.00	1.0	1.1	0.5
49	100	1100	1.0	8.7	45.00	0.5	2.9	0.5
50	101	1100	-0.3	6.7	82.00	0.0	3.2	0.0
51	102	1100	-0.7	8.0	76.00	0.5	1.8	1.2
52	103	1100	-0.5	12.5	53.00	0.5	1.2	0.0

Interpretation of *snomo.dat* file:

LINE 1 cell identification number, simulation year.

LINE 2 0.0, thermal diffusivity ($cm^2 min^{-1}$), heat conductivity ($calcm^{-2} min^{-1} \cdot K^{-1}$), emissivity (decimal), albedo (decimal), density (gm^{-3}): for new snow.

LINE 3 as line 2, but for old snow.

LINE 4 as line 2 and 3, but for sandy soil.

LINE 5 air pressure (mb), cloud type, instrument height (cm).

LINE 6 slope angle, aspect, start date, latitude.

LINE 7 lapse rate indicator.

LINE 8 vegetation cover type indicator.

LINE 9 initial snowdepth, (cm).

LINE 10 critical snowdepth (5cm).

LINE 11 depth of soil profile (cm), soil temperature at depth (°C), surface soil temperature (°C).

LINE 12 number of days in data file minus one.

LINES 13 daily meteorological data: Julian date, observation time, minimum air temperature (°C), maximum air temperature (°C),

TO 52 relative humidity (%), cloud cover (0-1), wind speed (ms^{-2}).

Table 1.2. Sample *snomo.dat* file for cell 24, W3, 1988.

```
1 24 1988
2 0.0 0.06 0.03 0.99 0.95 0.136
3 0.0 0.24 0.08 0.94 0.40 0.410
4 0.0 0.36 0.09 0.92 0.39 1.600
5 1010 5 100
6 6.27 -101.37 64 44.47
7 0
8 0
9 69.0
10 5.0
11 100.0 0.0 -1.0
12 39
13 64 1100 -11.1 -2.8 71.00 0.5 0.7 0.0
Lines 14 to 52 as file (1).
```

Table 1.3. Sample *snomo.dat* file for cell 1, W3, 1989.

```
1 1989
0.0 0.06 0.03 0.99 0.95 0.136
0.0 0.24 0.08 0.94 0.40 0.410
0.0 0.36 0.09 0.92 0.39 1.600
1010 5 100
6.15 -92.83 64 44.47
1
3
52.9
5.0
100.0 0.0 -1.0
46
64 1100 -8.5   0.7  96.00 0.5 0.3 7.1
65 1100 -19.9 -9.4  81.00 1.0 2.5 0.0
66 1100 -28.7 -15.8 65.00 0.5 1.7 0.0
67 1100 -20.4 -5.9  72.00 0.0 1.3 0.0
68 1100 -14.9 -1.2  67.00 0.0 1.4 0.0
69 1100 -11.5  1.8  52.00 0.5 1.7 0.0
70 1100 -7.6   2.02 47.00 0.5 1.9 1.02
71 1100 -12.6 -1.7  87.00 0.5 2.4 1.8
72 1100 -16.0 -1.3  40.00 0.0 1.2 0.0
73 1100 -3.9   8.6  61.00 0.5 1.0 0.0
74 1100  3.4   14.3 96.00 0.5 1.8 0.0
75 1100 -4.6   2.5  78.00 0.5 2.2 0.0
76 1100 -6.7   2.6  75.00 1.0 2.1 3.1
77 1100 -8.1   1.0  97.00 0.5 0.4 17.0
78 1100 -12.5 -6.1  84.00 0.5 1.7 1.02
79 1100 -12.1 -0.6  87.00 1.0 1.2 1.52
80 1100 -9.3  -0.9  94.00 0.5 2.0 7.6
81 1100 -14.3 -3.6  57.00 0.5 1.8 0.0
82 1100 -10.7  2.6  47.00 0.0 1.8 0.0
83 1100 -9.4   2.2  55.00 0.5 1.8 2.5
84 1100 -2.7   6.3  89.00 0.5 0.8 3.1
85 1100  0.0   6.5  91.00 0.5 1.1 0.0
86 1100  0.0   16.9 60.00 0.5 0.9 0.0
87 1100  7.0   17.1 79.00 0.2 0.8 2.3
88 1100 -0.2   13.8 65.00 1.0 1.7 13.5
89 1100 -2.4   0.4  93.00 0.5 1.2 18.3
90 1100 -2.7   0.3  97.00 1.0 0.6 10.2
91 1100 -2.3   0.2  94.00 0.5 1.9 4.3
92 1100 -3.4   6.5  83.00 0.5 1.3 0.0
93 1100  1.0   3.8  94.00 1.0 1.1 26.2
94 1100  1.2   4.6  99.00 1.0 0.8 6.9
95 1100  4.3   14.0 90.00 0.4 0.9 8.4
96 1100  0.1   6.5  98.00 0.5 1.9 21.3
97 1100  0.1   4.2  94.00 0.6 1.7 9.4
```

continued overleaf...

47	98	1100	-3.4	2.6	82.00	0.5	2.4	0.0
48	99	1100	-4.9	6.2	43.00	0.5	1.3	3.1
49	100	1100	-5.7	1.2	70.00	0.5	1.6	6.6
50	101	1100	-7.9	-0.2	70.00	0.7	1.7	0.0
51	102	1100	-7.1	4.2	66.00	0.5	0.7	0.0
52	103	1100	-1.1	5.9	58.00	0.5	1.9	0.0
53	104	1100	-0.3	5.2	73.00	0.9	1.1	0.0
54	105	1100	0.4	6.8	71.00	0.5	2.1	6.4
55	106	1100	1.0	4.6	97.00	0.5	0.9	4.6
56	107	1100	3.5	14.7	80.00	0.5	0.8	0.0
57	108	1100	0.4	11.1	95.00	0.5	2.4	3.8
58	109	1100	-0.9	5.9	53.00	0.5	1.9	0.0
59	110	1100	-0.6	5.2	90.00	0.5	2.1	1.8

Table 1.4. Description of variables in *snomo.dat*.

LINE	VARIABLE	REAL/ INTEGER	DESCRIPTION
1	CELL	I	Number of cell.
	YEAR	I	Year of simulation
2	VNEWSN(1,1)	R	New snow vector, 0.0.
	VNEWSN(1,2)	R	" " " , thermal diffusivity ($cm^2 min^{-1}$).
	VNEWSN(1,3)	R	" " " , heat conductivity ($calcm^{-2} min^{-1} \cdot K^{-1}$).
	VNEWSN(1,4)	R	" " " , emissivity (decimal).
	VNEWSN(1,5)	R	" " " , albedo (decimal).
	VNEWSN(1,6)	R	" " " , density (gcm^{-3}).
3	VOLDSN(1,1)	R	Old snow vector, 0.0.
	VOLDSN(1,2)	R	" " " , thermal diffusivity ($cm^2 min^{-1}$).
	VOLDSN(1,3)	R	" " " , heat conductivity ($calcm^{-2} min^{-1} \cdot K^{-1}$).
	VOLDSN(1,4)	R	" " " , emissivity (decimal).
	VOLDSN(1,5)	R	" " " , albedo (decimal).
	VOLDSN(1,6)	R	" " " , density (gcm^{-3}).
4	VSOIL(1,1)	R	Soil vector, 0.0.
	VSOIL(1,2)	R	" " , thermal diffusivity ($cm^2 min^{-1}$).
	VSOIL(1,3)	R	" " , heat conductivity ($calcm^{-2} min^{-1} \cdot K^{-1}$).
	VSOIL(1,4)	R	" " , emissivity (decimal).
	VSOIL(1,5)	R	" " , albedo (decimal).
	VSOIL(1,6)	R	" " , density (gcm^{-3}).
5	PRESS	I	Air pressure (mb).
	NCLOUD	I	Cloud type, see table 1.2.
	ZA	I	Instrument height (cm).
6	SLOPE1	R	Cell slope angle (°)
	SURFC1	R	Cell aspect (°)
	DAY1	I	Start date (Julian calender).
	LAT	R	Latitude of catchment (°).
7	ILAPSE	I	Lapse rate indicator. ILAPSE=0, elevation band 1500-2000ft. ILAPSE=1, elevation band 1000-1500ft.
8	IVEG	I	Cell vegetation cover type indicator. IVEG=1, coniferous cover. IVEG=2, deciduous cover. IVEG=3, mixed cover. IVEG=0, pasture and clear-cut (open).

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9	SNDP1	R	Initial snowdepth (cm).
10	CRI[illegible]	R	Critical snowdepth (5cm).
11	SOILDP	R	Depth of soil profile (cm).
	SOILTP	R	Soil temperature at depth (°C).
	SSOLTP	R	Surface soil temperature (°C).
12	N	I	Number of days to be modelled. Number of daily meteorological data days minus 1.
13			Daily meteorological data.
	XXX(1,8)	I	Date (Julian calender).
	XXX(1,1)	I	Observation time (24hr clock).
	YYY(1,1)	R	Minimum daily air temperature (°C).
	YYY(1,9)	R	Maximum daily air temperature (°C).
	YYY(1,2)	R	Relative humidity (%).
	YYY(1,3)	I	Cloud cover (0-1).
	YYY(1,6)	R	Wind speed (ms^{-1}).
	YYY(1,7)	R	Precipitation (mm water).

LINE 1

1. CELL

The number of the cell. Each cell is numbered for easy identification.

2. YEAR

The year of the simulation.

LINE 2: 'New' snow vector.

The vector for the physical characteristics of 'new' snow. Chapter 4 (volume 1) considered the division of the physical characteristics of snow into those commonly associated with 'new' (fresh) snow and 'old' snow. Values are taken from various sources or measurements on site if available. The physical characteristics required are thermal diffusivity (cm^2min^{-1}), heat conductivity ($calcm^{-2}min^{-1} \cdot K^{-1}$), emissivity (decimal), albedo (decimal) and density (gcm^{-3}). The first value in the vector is always input as zero. This is because it represents snowpack depth and is calculated within the program.

LINE 3: 'Old' snow vector.

As line 2, except concerned with the values of the physical characteristics of 'old' snow.

LINE 4: Soil vector.

As lines 2 and 3, except concerned with the values of the physical characteristics of the soil. Soil type is taken as the predominant soil type for that particular cell or catchment. The soil vector is rarely used and therefore the accuracy of the soil values is not particularly important. Again values can be taken from the literature, or on site.

LINE 5

1. PRESS.

Air pressure (mb). The average air pressure for the simulation period is used, or a median value.

2. NCLOUD.

Values for cloud cover type are contained in table 1.5. The average cloud cover type is used or, in the absence of sufficient data, a default cloud cover type of 5 (stratocumulus) is used.

3. ZA.

Instrument height is the average height (cm) of the instruments used to measure the meteorological data, ie. wind speed and relative humidity, from the ground/snow surface. If this measurement is unavailable or is too variable a default value of 100cm is used.

LINE 6

1. SLOPE1.

Cell slope angle (°).

2. SURFC1.

Cell aspect. The cell aspect is measured in degrees from South with westerly values positive and easterly values negative, ie. West=+90° and East=-90°.

3. DAY1.

Date of start of simulation, Julian calender.

4. LAT.

Latitude of catchment or cell (degrees and minutes). The latitude of the midpoint or mouth of the catchment can be used, at the operator's discretion.

LINE 7

1. ILAPSE.

Lapse rate indicator. SNOMO is currently set up for the W3 catchment, Sleepers River Research Watershed, Danville, Vermont. When subdivided the elevations derived for each cell ranged within 1000-2000ft a.s.l.. A midpoint of 1500ft a.s.l. was used as a

Table 1.5. Cloud Genera and Cloud Type Indices*, Balick et.al. (1981a).

Cloud Genera	Abbreviation	Index value	Comments
Cirrus	Ci	1	High clouds composed of white delicate filaments, patches of narrow bands, elements often curved or slanted and smaller than Cs, never overcast or precipitating.
Cirrostratus	Cs	2	High clouds appearing as whitish veil usually fibrous, often produces halo phenomena, thinner than As, does not appear to move, nonprecipitating.
Altocumulus	Ac	3	Midlevel clouds, patches, usually broken, lee wave clouds, elements smaller than Sc, nonprecipitating.
Altostratus	As	4	Midlevel grey sheet or layer of striated, fibrous or uniform appearance, large horizontal extent; thicker than Cs, thinner than Ns, precipitation generally light and continuous (if any).
Stratocumulus	Sc	5	Grey and/or whitish layer or patch, nearly always has dark spots and is nonfibrous; elements larger than Ac, nonprecipitating.
Stratus	St	6	Grey rather uniform base, patches ragged if present, precipitation unusual but light and continuous if present, lower and more uniform than Sc, less dense and less 'wet' than Ns.
Nimbostratus	Ns	7	Grey often dark, diffuse, large horizontal and vertical extent, thicker than As, more uniform than Sc, often precipitating, precipitation continuous.
Fog	FG	8	

* Cloud genera; Cumulus (Cu), Cirrocumulus (Cc) and Cumulonimbus (Cb) are not treated here. At low cloud covers (0.3) Cu and Cc may be approximated with Ac.

further subdivision of the elevation resulting in 2 elevation bands: 1000-1500ft and 1500-2000ft. If the elevation of the cell is between 1000-1500ft the lapse rate indicator is set to 1, if between 1500-2000 then it is set to 0. The elevation bands can be altered if required.

LINE 8

1. IVEG.

Vegetation cover type indicator. Four vegetation cover types can be modelled using SNOMO:

IVEG=1, coniferous cover

IVEG=2, deciduous cover

IVEG=3, mixed cover

IVEG=0, pasture or clear-cut (open).

The vegetation cover types are those found at W3. Again, as with ILAPSE, these can be altered if necessary.

LINE 9

1. SNDP1.

Initial snowdepth. This is the known (measured or estimated) snowdepth for the cell at the start of the simulation. If estimated the value for initial snowdepth is based on the relationship between snowdepth, vegetation cover type and elevation. If one value at a base station (1500-2000ft a.s.l) is available then:

(1) Cell with elevation < 1500ft a.s.l., -10cm.

(2) Cell with coniferous forest cover, -5cm.

(3) Cell with mixed forest cover, +5cm.

(4) Cell with deciduous forest cover, +10cm.

These values can be used or compiled according to another catchment.

LINE 10

1. CRITDP.

Critical depth (5cm). This is the depth below which, because of the difficulty of accurate measurement, no snow is said to be

present.

LINE 11

1. SOILDP.

Depth of soil profile (cm). Default value is 100cm.

2. SOILTP.

Soil temperature at depth (°C). Default value is 0°C. SNOMO does not currently model the temperatures within the soil or the heat flux across the ground/snow interface (Q_g) and therefore the accuracy of SOILTP is not vital.

3. SSOLTP.

Surface soil temperature (°C). Default value of -1°C is used. Again, for the same reasons as SOILTP, accuracy is not vital.

LINE 12

1. N

The number of days to be modelled in the simulation. This is calculated as the number of daily meteorological data available in *snomo.dat* minus one.

LINE 13 and onward : Daily meteorological data.

1. XXX(1,8)

Julian date.

2. XXX(1,1)

Observation time (24hr clock), default value of 1100hrs.

3. YYY(1,1)

Minimum air temperature (°C).

4. YYY(1,9)

Maximum air temperature (°C).

5. YYY(1,2)

Relative humidity (%).

6. YYY(1,3)

Cloud cover amount (decimal).

7. YYY(1,6)

Wind speed (ms^{-1})

8. YYY(1,7)

Precipitation (mm water).

Table 1.6 is provided for the guidance of the compilation of a *snomo.dat* file.

1.2.2 *conif.dat*, *decid.dat* and *mix.dat*.

These three data files contain the information required if the vegetation cover options of coniferous, deciduous or mixed cover are used. The files contain values of the variables σ_f, χ, ϵ_f, α_f and z_f. Examples of the three data files used for the W3 simulation are shown in table 1.7. The variables contained in the files are considered in chapter 4 (volume 1) and below:

1. σ_f, foliage cover fraction (0-1).

This describes the density of the vegetation cover. σ_f=0 represents no foliage and therefore no radiative shielding and σ_f=1 represents complete radiative blocking. Table 1.4 shows various limiting values of σ_f taken from Geiger (1965) and Deardorff (1978) for various vegetation covers.

2. χ, state of vegetation (1-1000).

χ is used as a multiplier of the stomatal resistance function. A summer value, when the vegetation is healthy and active, is 1, a winter and therefore dominant or dead vegetation cover value is 1000. Other values can be chosen to adjust stomatal resistance for moisture stress, senescence or other factors.

3. ϵ_f, foliage emissivity (decimal).
4. α_f, foliage albedo (decimal).
5. z_f, foliage height (cm).

Values for ϵ_f and α_f can be obtained from the literature.

Table 1.6. Compilation guideline for *snomo.dat*.

All input on the same line is separated by at least 1 space and starts in the first column.

LINE 1

1. Number of cell ________
2. Year of simulation ________

LINE 2

1. 0.0 0.0
2. New snow thermal diffusivity ________
3. " " heat conductivity ________
4. " " emissivity ________
5. " " albedo ________
6. " " density ________

LINE 3

1. 0.0 0.0
2. Old snow thermal diffusivity ________
3. " " heat conductivity ________
4. " " emissivity ________
5. " " albedo ________
6. " " density ________

LINE 4

1. 0.0 0.0
2. Soil thermal diffusivity ________
3. " heat conductivity ________
4. " emissivity ________
5. " albedo ________
6. " density ________

continued overleaf...

LINE 5

1. Air pressure __________
2. Cloud type __________
3. Instrument height __________

LINE 6

1. Cell slope angle __________
2. Cell aspect __________
3. Start date __________
4. Latitude of catchment or cell __________

LINE 7

1. Lapse rate indicator __________

LINE 8

1. Cell vegetation cover type indicator __________

LINE 9

1. Initial snowdepth __________

LINE 10

1. Critical snowdepth __________

LINE 11

1. Depth of soil profile __________
2. Soil temperature at depth __________
3. Surface soil temperature __________

LINE 12

1. Number of days to be modelled __________

continued overleaf...

LINE 13

1. Julian date ____________
2. Cbservation time ____________
3. Minimum daily air temperature ____________
4. Maximum daily air temperature ____________
5. Relative humidity ____________
6. Cloud cover amount ____________
7. Wind speed ____________
6. Precipitation ____________

Table 1.7. *conif.dat*, *decid.dat* and *mix.dat* files used for W3.

conif.dat:	0.70,1000,0.98,0.10,2000
decid.dat:	0.50,1000,0.97,0.15,2000
mix.dat:	0.60,1000,0.975,0.125,2000

Interpretation:

1. σ_f, foliage cover fraction (0-1)
2. χ, state of vegetation (1-1000)
3. ϵ_f, foliage emissivity (decimal)
4. α_f, foliage albedo (decimal)
5. z_f, foliage height (cm).

Table 1.8. *lapse.dat* file used for W3.

lapse.dat: 2.0,1.0

Interpretation:

1. TMAX, lapse rate factor for daily maximum temperature (°C).
2. TMIN, lapse rate factor for daily minimum temperature (°C).

1.2.3 *lapse.dat*.

The file *lapse.dat* contains values for TMAX and TMIN. These are the lapse rate alteration of the maximum (TMAX) and minimum (TMIN) daily air temperatures. The values for the lapse rate alteration are those used for the catchment W3 and are obtained from the literature (chapters 4 and 6, volume 1). If applied to different catchments the values can be altered if necessary. An example of the *lapse.dat* file used for the W3 simulation is shown in table 1.8.

CHAPTER 2: OUTPUT

2.1 Output file.

Table 2.1 shows the output file *SNOMO.RES* for cell 1, W3, 1988. The input file used was that shown in table 1.1. The output variables are considered below in the order in which they appear in *SNOMO.RES* and using the titles used in *SNOMO.RES*.

1. CELL NO.

   The identification number of the cell.

2. YEAR

   The year of the simulation.

3. JULIAN DATE

   Date, Julian calender.

4. SNOWDEPTH

   Calculated depth of snowpack (cm).

5. SNOWMELT

   Calculated daily depth of snow melted, in both centimetres of snow and millimetres of water equivalent.

6. SNOWFALL

   Daily snowfall (mm water equivalent). The value for snowfall on the first day of simulation is equal to the initial snowpack depth and is not related to the amount of daily snowfall.

7. DENSITY

   Daily average snowpack density (gcm^{-3}).

8. RAIN-ON-SNOW

   Occurrence of a rain-on-snow event. 1=rain-on-snow event, 0=no rain-on-snow event.

Table 2.1. Sample *SNOMO.RES* file, for cell 1, W3, 1988

CELL NO.: 1

YEAR: 1988

JULIAN DATE	SNOWDEPTH (cm)	SNOWMELT (cm snow)	(mm water)	SNOWFALL (cm)	DENSITY (G/M**3)	RAIN-ON-SNOW (1=yes, 0=no)
64.00	69.00	0.00	0.00	69.00	0.39	0
65.00	69.15	0.00	0.00	0.15	0.39	0
66.00	69.15	0.00	0.00	0.00	0.39	0
67.00	66.81	0.00	0.00	1.10	0.39	0
68.00	66.88	0.00	0.00	0.07	0.41	0
69.00	71.37	0.00	0.00	4.49	0.41	0
70.00	72.55	0.00	0.00	1.18	0.39	0
71.00	73.28	0.00	0.00	0.74	0.38	0
72.00	73.28	0.00	0.00	0.00	0.38	0
73.00	71.75	0.00	0.00	3.53	0.38	0
74.00	72.78	0.00	0.00	1.03	0.40	0
75.00	73.66	0.00	0.00	0.88	0.39	0
76.00	75.13	0.00	0.00	1.47	0.39	0
77.00	75.29	0.00	0.00	0.07	0.38	0
78.00	75.20	0.00	0.00	0.00	0.38	0
79.00	70.90	0.00	0.00	0.37	0.38	0
80.00	67.05	5.91	24.24	2.06	0.41	0
81.00	61.97	5.45	22.34	0.37	0.41	0
82.00	60.20	1.77	7.26	0.00	0.41	0
83.00	60.20	0.00	0.00	0.00	0.41	0
84.00	58.35	1.85	7.60	0.00	0.41	0
85.00	55.32	3.03	12.42	0.00	0.41	0
86.00	50.89	4.43	18.14	0.00	0.41	1
87.00	54.10	4.66	19.13	7.87	0.41	0
88.00	54.98	0.00	0.00	0.88	0.39	0
89.00	54.98	0.00	0.00	0.00	0.39	0
90.00	52.25	0.00	0.00	0.00	0.39	0
91.00	47.58	4.67	19.14	0.00	0.41	0
92.00	43.43	4.16	17.04	0.00	0.41	0
93.00	38.68	4.75	19.46	0.00	0.41	0
94.00	34.08	4.60	18.85	0.00	0.41	1
95.00	30.26	3.83	15.69	0.00	0.41	1
96.00	25.42	4.84	19.83	0.00	0.41	1
97.00	19.96	5.46	22.38	0.00	0.41	0
98.00	14.72	5.24	21.49	0.00	0.41	0
99.00	9.87	4.85	19.88	0.00	0.41	1
100.00	4.00	5.86	24.10	0.00	0.41	1

CHAPTER 3: PROGRAMME DETAILS

3.1. Programme structure.

Chapter 4, volume 1, considers in detail the equations used by SNOMO to calculate snowdepth within one cell. This chapter presents the programme logic that enables these equations to be utilised and to interact successfully. Figure 3.1 shows the SNOMO programme logic. SNOMO broadly consists of 2 sections:

(1) Control programme.

This is responsible for the determination of he type of precipitation, the calculation of melt, the calculation of the affect of a rain-on-snow event, the calculation of the heat flux across the ground/snow interface (Q_g), various operational markers, the calculation of the depth of the snowpack and the physical characteristics of the snowpack, the model input and the model output.

(2) Algorithm to calculate the majority of the components of the snowpack energy budget.

This algorithm is responsible for the calculation of the snowpack energy budget components $K\downarrow$, $K\uparrow$, $L\downarrow$, $L\uparrow$, Q_c and Q_e and the snowpack surface and internal temperatures. The algorithm is adapted from the US Corps of Engineers Terrain surface Temperature Model (TSTM) as developed by Balick et.al. (1981a & b). The basic equations used by the original TSTM remain the same as in the modified TSTM. TSTM has been heavily modified from its original state as presented in Balick et.al. (1981a & b) and has also been incorporated into the logic structure of SNOMO. The logic structure of TSTM is shown in figure 3.2. TSTM is operational for situations where a vegetation cover is present or absent. Vegetation cover is modelled using a vegetation cover algorithm, VEGIE, within TSTM.

The relationship between TSTM and VEGIE is shown in figure 3.3.

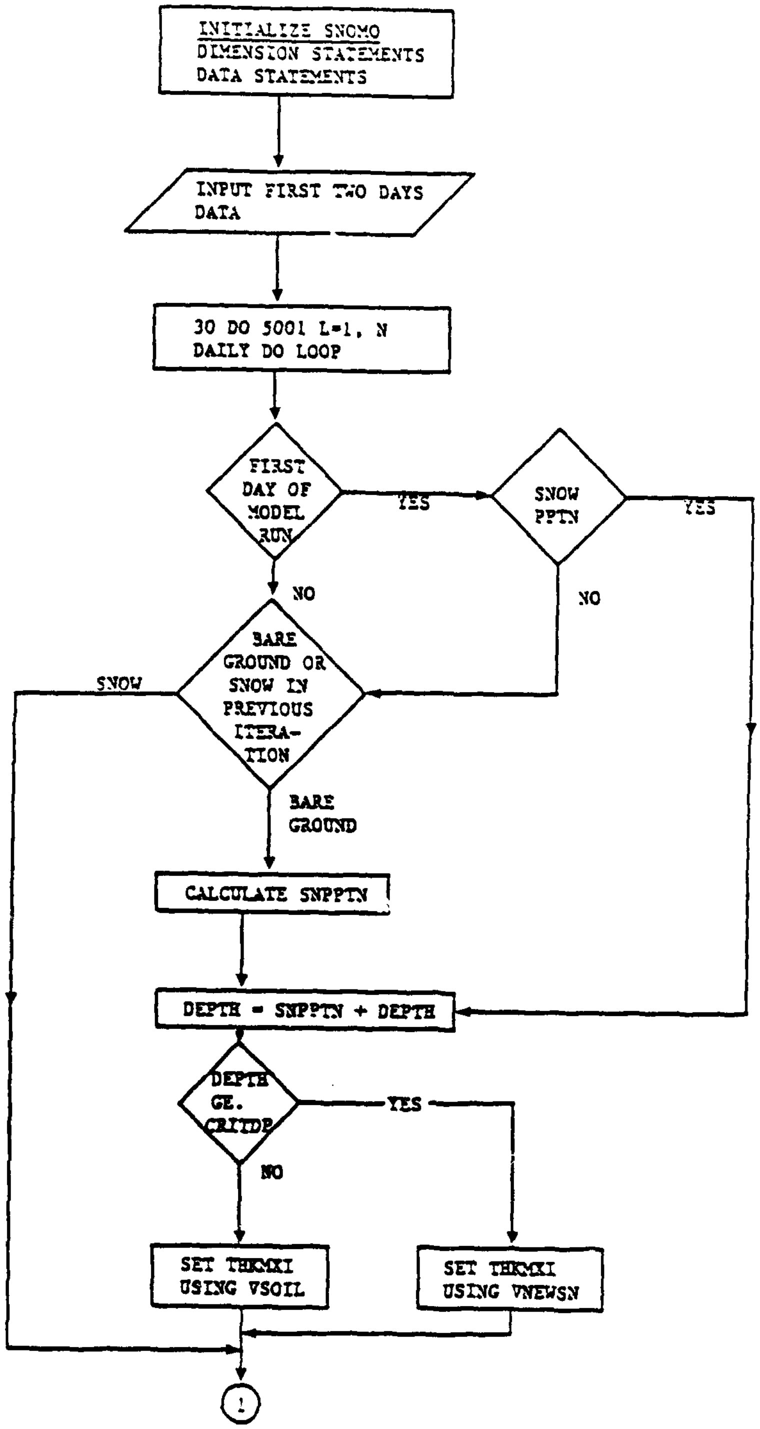

Figure 3.1. Simplified flowchart for SNOMO (sheet 1 of 4).

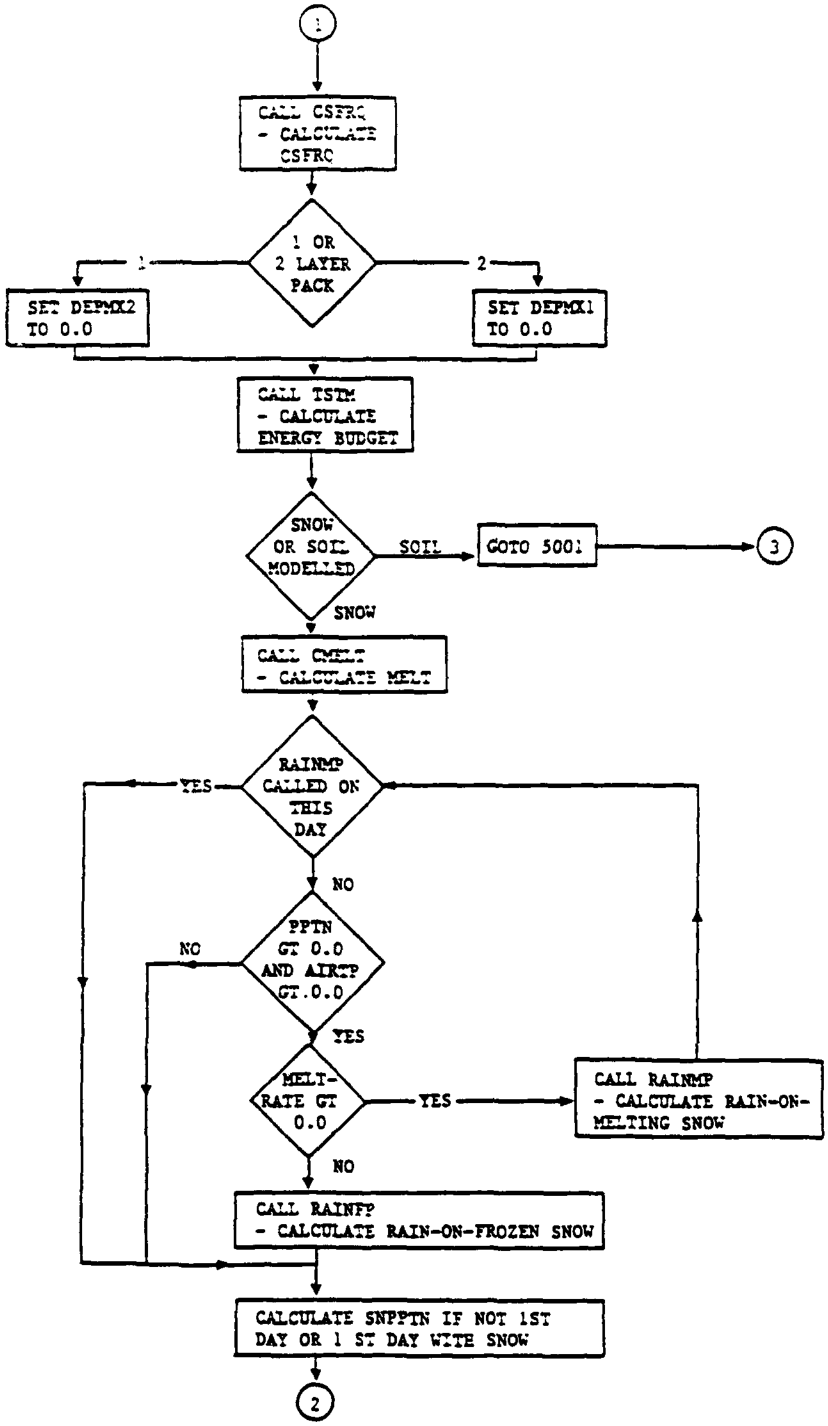

Figure 3.1. Simplified flowchart for SNOMO (sheet 2 of 4).

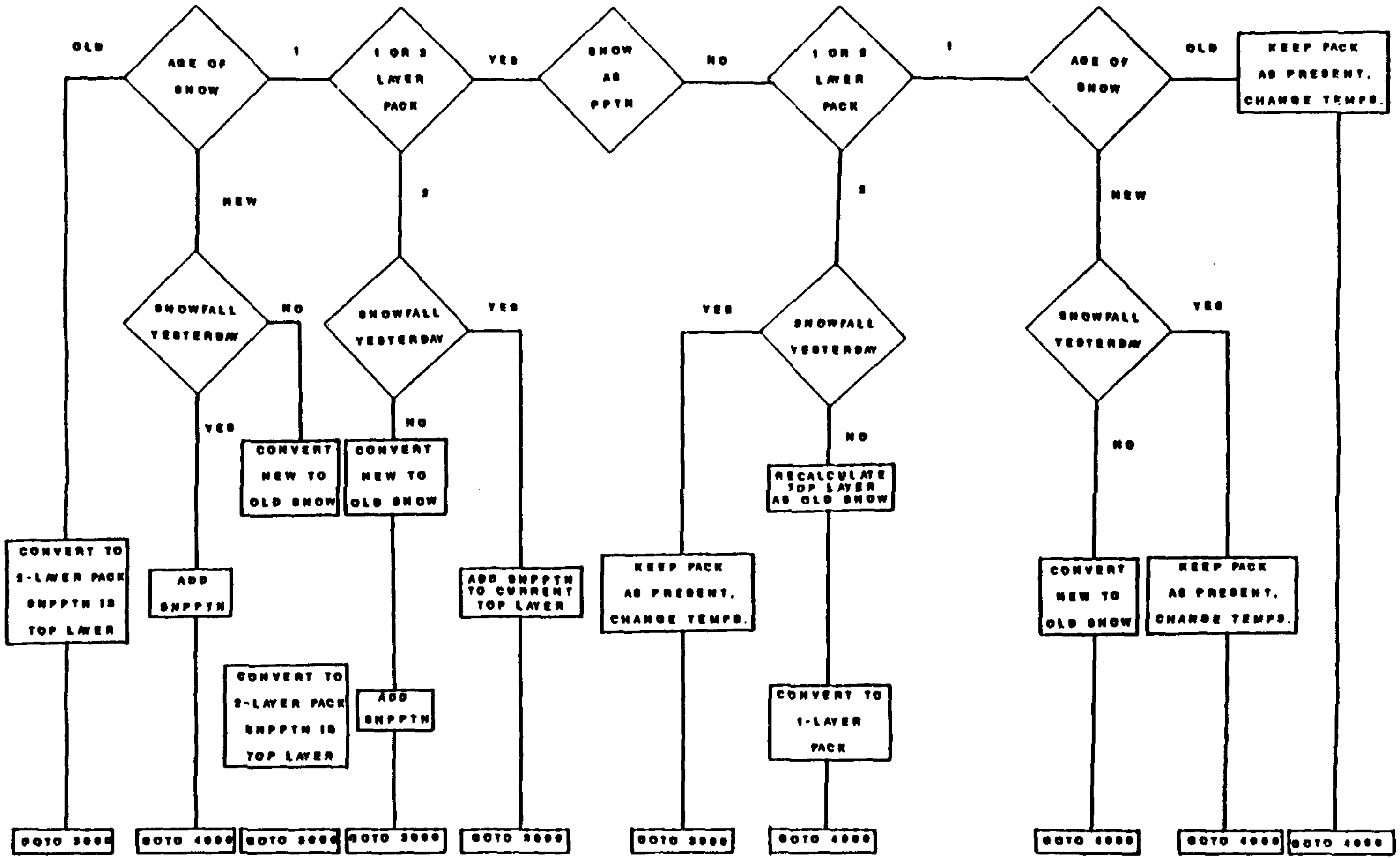

Figure 3.1. Simplified flowchart for SNOMO (sheet 3 of 4).

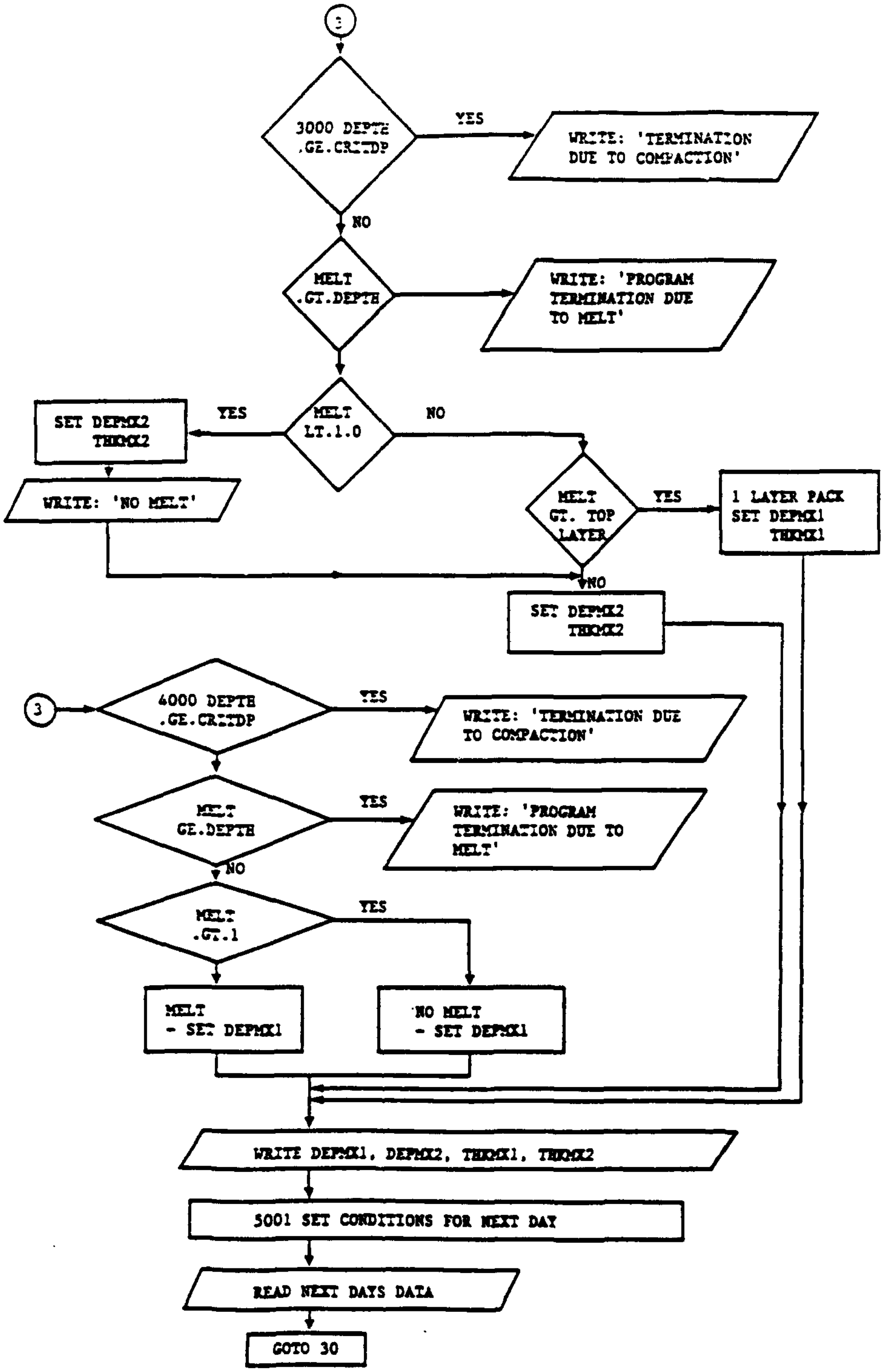

Figure 3.1. Simplified flowchart for SNOMO (sheet 4 of 4).

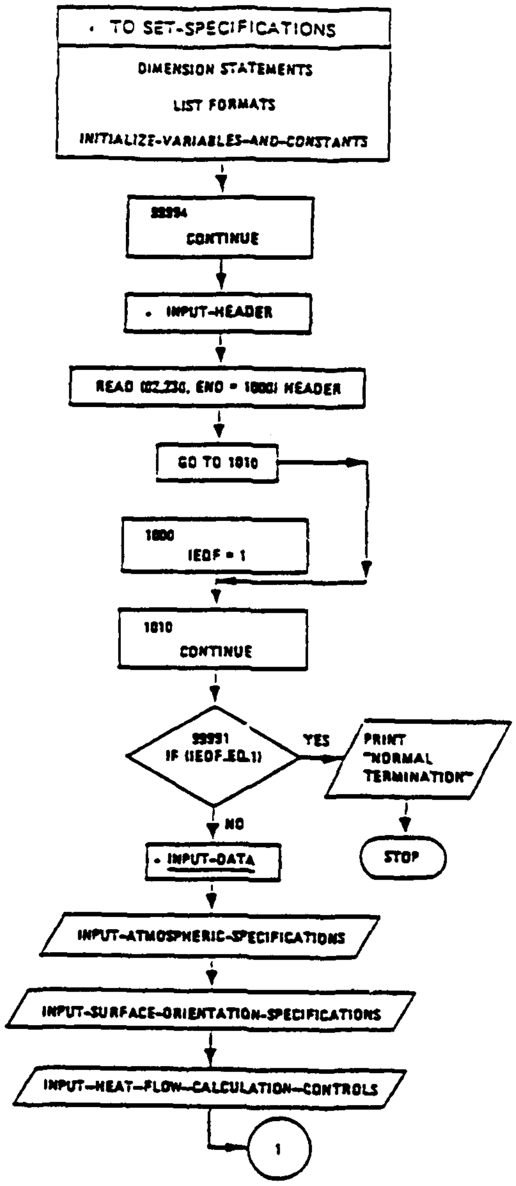

Figure 3.2. Simplified flowchart for TSTM, Balick et.al., 1981a (sheet 1 of 5).

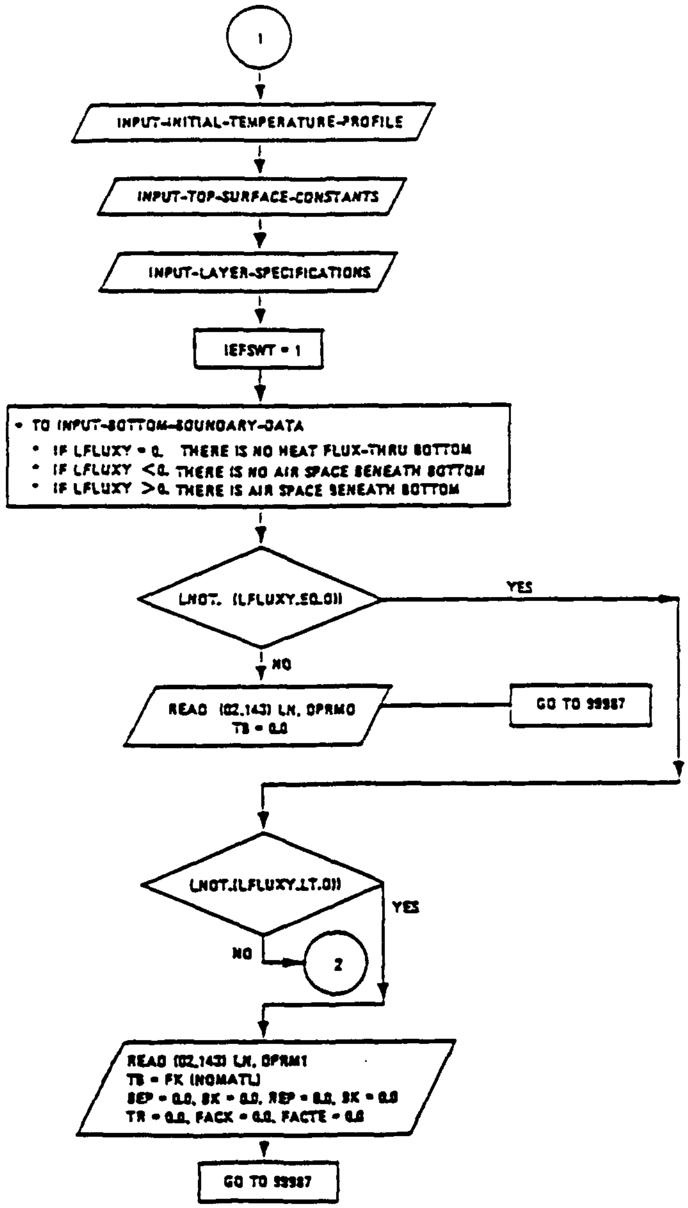

Figure 3.2. Simplified flowchart for TSTM, Balick et.al., 1981a (sheet 2 of 5).

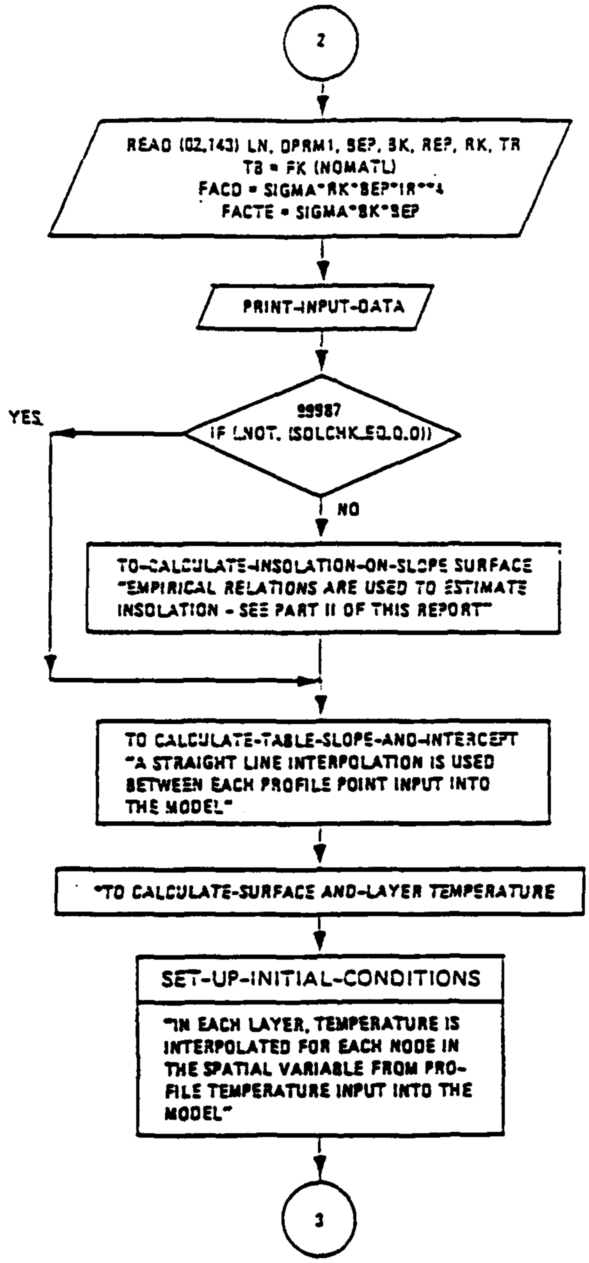

Figure 3.2. Simplified flowchart for TSTM, Balick et.al., 1981a (sheet 3 of 5).

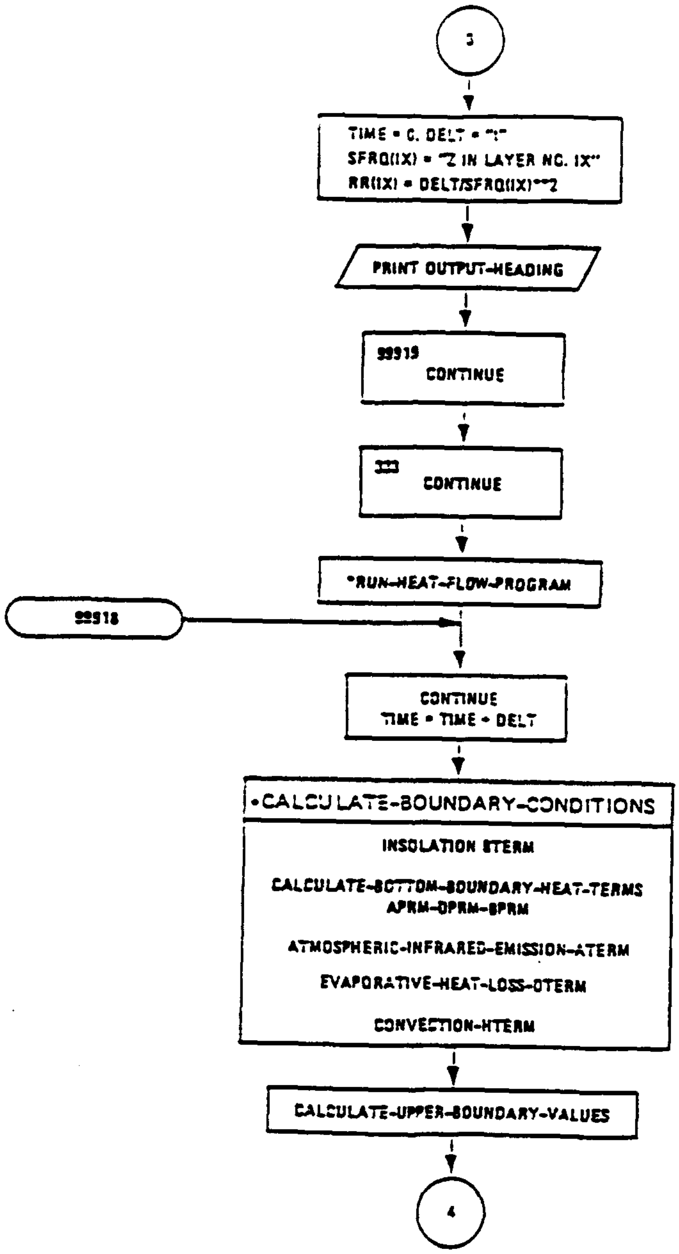

Figure 3.2. Simplified flowchart for TSTM, Balick et.al., 1981a (sheet 4 of 5).

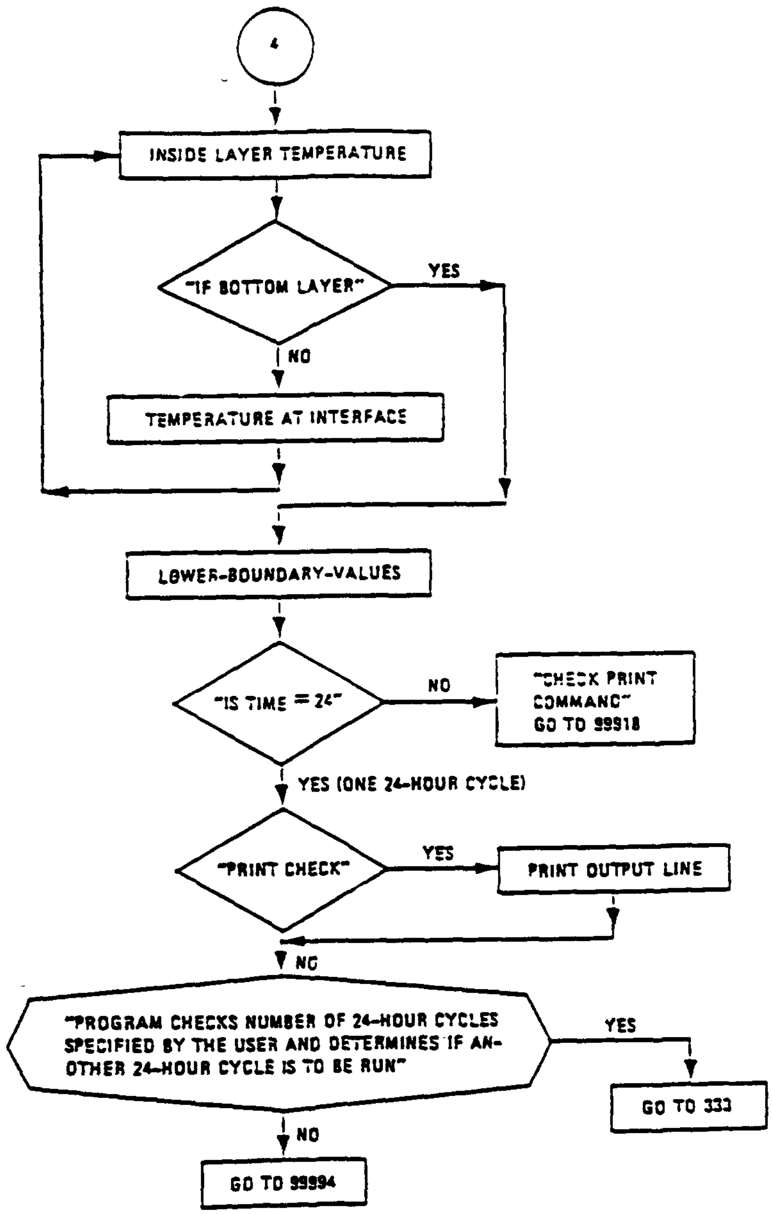

Figure 3.2. Simplified flowchart for TSTM, Balick <u>et.al.</u>, 1981a (sheet 5 of 5).

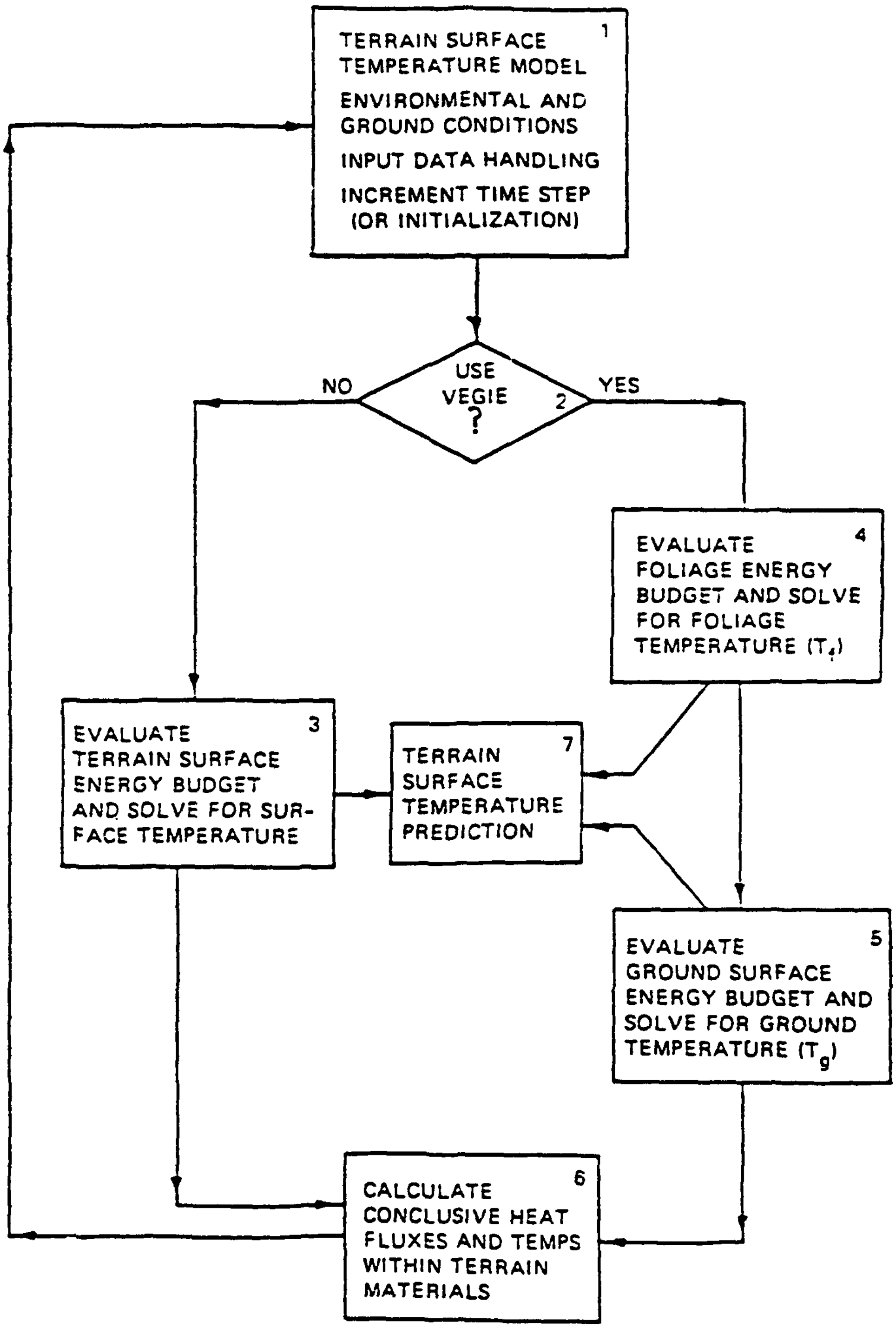

Figure 3.3. Sequence of calculation of the major components of the TSTM/VEGIE system, Balick et.al. (1981b).

In block 1 the model is incremented one time step or initialized, or terminated) in accordance with procedures established for TSTM. In block 2 the decision whether to utilize VEGIE or not is made. If VEGIE is not used a non-vegetated surface energy budget is evaluated as an upper boundary condition (block 3) for the solution of the equation of heat transfer through the terrain materials (block 6). The solution for the surface temperature (block 7) comes from the evaluation of the surface energy budget equation and therefore to solve the heat transfer equation. In order to achieve this the heat conduction term and the distribution of heat in terrain materials must be calculated (block 6). If VEGIE is used, the energy budget of block 3 is replaced by blocks 4 and 5. Blocks 4 and 5 comprise VEGIE. Block 4 calculates the energy budget for the foliage that includes a contribution from the ground surface. Block 5 calculates the energy budget for the ground surface that includes a contribution from the foliage layer.

Solutions of temperature for the foliage (from block 4) and the ground (from block 5) are performed by a simple root-finding algorithm and are combined according to the proportion of foliage cover to yield an average, or effective, temperature of the vegetated surface. The ground energy budget is then used in the evaluation of heat flow in the terrain (block 6), and the programme returns to block 1.

3.2. Additional information.

SNOMO can be altered very simply in order to produce, in the output file, the hourly energy budget values for the snowpack of $K\downarrow$, $K\uparrow$, $L\downarrow$, $L\uparrow$, Q_c and Q_e. The alterations are found under the heading 'OPTION 2' in the hardcopy of the programme (section 3.3.)

The absence of a mass conservation routine was discussed in volume 1. A mass conservation routine has been written and tested (chapter 7, volume 1) and is included in the hardcopy of the

programme (section 3.3.) as 'OPTION 3'.

3.3. Programme code.

Copies of *snomo.f*, *snomo.dat*, *decid.dat*, *conif.dat*, *mix.dat*, *lapse.dat* and *SNOMO.RES* are available on the floppy disc inserted at the back of this volume. A fully commented hardcopy of the programme code is presented in the following pages.

```
C-------------------------------------------------------------------
C                          SNOMO.F, JUNE 1991
C                                 BY
C                         KATHERINE M. SAMBLES
C-------------------------------------------------------------------
C
C THIS IS A DISTRIBUTED PHYSICALLY-BASED SNOWMELT MODEL.  SNOMO.F IS
C DESIGNED TO OPERATE IN CONJUNCTION WITH A GIS DECISION AND DATA
C MANIPULATION STRUCTURE WHICH DIVIDES THE CATCHMENT THAT IS TO BE
C MODELLED INTO HOMOGENEOUS SUBDIVISIONS, CALLED CELLS.  SNOMO.F
C CALCULATES THE ENERGY-BUDGET OF THE SNOWPACK AT THE MID-POINT OF
C ONE CELL AND CALCULATES THE RESULTANT CHANGE IN SNOWPACK PROPERTIES
C AND MELTWATER RUNOFF.  USING THE RESULTS FOR EACH CELL AND THE GIS
C STRUCTURE A MAP OF THE SNOWCOVER DISTRIBUTION AND DEPTH DISTRIBUTION
C CAN BE OBTAINED.  SNOMO.F IS DEVELOPED FROM THE WES MODEL TSTM AND
C THE SUBMODEL VEGIE WAS INCORPORATED INTO SNOMO.F IN MARCH 1989 WITH
C THE HELP OF DR. RANDY SCOGGINS, WES.
C
C SNOMO.F IS DIVIDED INTO 2 MAJOR PARTS:
C (1)  THE MAIN PROGRAM.  THIS CALCULATES MELT, MANIPULATES THE
C      SNOWPACK DEPTH AND PHYSICAL CHARACTERISTICS AND HANDLES THE
C      MODEL INPUT AND OUTPUT.
C (2)  THE SUBROUTINE TSTM.  THIS CALCULATES THE COMPONENTS OF THE
C      ENERGY-BUDGET OF THE SNOWPACK.
C SNOMO.F REQUIRES THE DATA FILES SNOMO.DAT, LAPSE.DAT, DECID.DAT,
C MIX.DAT AND CONIF.DAT IN ORDER TO OPERATE.  THE OUTPUT FILE IS
C SNOMO.RES.  A FULL LISTING OF ALL THE VARIABLES USED IS INCLUDED
C AT THE END OF THE PROGRAM CODE.
C THERE ARE 3 CODE OPTIONS FOR SNOMO.F:
C  OPTION 1 IS THE DEFAULT OPTION.  OPTION 1 IS UTILISED UNLESS OTHERWISE STATED.
C  OPTION 2 GIVES AN OUTPUT OF HOURLY ENERGY-BUDGET VALUES.
C  OPTION 3 INCLUDES A MASS CONSERVATION ROUTINE.
C
C -------------------------------------------------------------------
C
C INITIALISATION, DECLARATION, DATA STATEMENTS.
C
      COMMON/MATRX1/XXX(30,10),YYY(30,10)
      COMMON/MATRX2/DEPMX1(2,2),DEPMX2(3,2)
      COMMON/MATRX3/THKMX1(1,6),THKMX2(2,6)
      COMMON/VECTOR/VNEWSN(1,6),VOLDSN(1,6)
      COMMON/TSTM1/PRESS,NCLOUD,ZA,SLOPE1,SURFC1,DAY,LAT
      COMMON/TSTM2/NOMATL,NIPTS
      COMMON/VEGI/IVEG,SIGF,STATE,EPF,ALBEDO,HFOL
      COMMON/RAIN/AIRTP
      COMMON/SFRQ/SFRQ(6)
      REAL SNPPTN,SNVOL,CRITDP,HCAPSN,DENSN,
   &  DENW,HCAPW,LHEATF,DEPTH,PTERM,NETRAD,AVSTP,
   &  AVBTTP,PPTN,DAY1,LAT,TGBR,TSOL,TABSOR,TATERM,THTERM,
   &  TDTERM,VSOIL(1,6),WE1,DEPTH1,MRWE,MRSN,BOTTP,STP,XSNTP,
   &  SPHTI,SPHTW,SNDP1,TMAX,TMIN
```

```
      INTEGER I,J,N,K1,K2,K3,K10,K30,KONTRL,ILAPSE,IVEG,ISNOW,
     & IRAIN,CELL,YEAR
C
C LATENT HEAT OF FUSION IS 0.334 MJkg-1
C SPECIFIC HEAT OF ICE IS GIVEN IN MJkg-1.K-1 = 2.10E+3 Jkg-1.K-1
C SPECIFIC HEAT OF WATER IS GIVEN IN KJkg-1.K-1 = 4.18E+3 Jkg-1.K-1
C
      DATA DENW,HCAPW,HCAPSN,LHEATF/1000.0,4.21,2.09,0.334/
      DATA SPHTI,SPHTW/0.0021,4.18/
      DATA TOTTIM,TFRQ,TPRNT/1,1.0,60.0/
      NIN=10
      NCONIF=11
      NLAPSE=12
      NDECID=13
      NMIX=14
      NOUT=9
      OPEN(UNIT=NIN,FILE='SNOMO.DAT',STATUS='OLD')
      REWIND NIN
      OPEN(UNIT=NCONIF,FILE='CONIF.DAT',STATUS='OLD')
      REWIND NCONIF
      OPEN(UNIT=NLAPSE,FILE='LAPSE.DAT',STATUS='OLD')
      REWIND NLAPSE
      OPEN(UNIT=NDECID,FILE='DECID.DAT',STATUS='OLD')
      REWIND NDECID
      OPEN(UNIT=NMIX,FILE='MIX.DAT',STATUS='OLD')
      REWIND NMIX
      OPEN(UNIT=NOUT,FILE='SNOMO.RES')
      REWIND NOUT
C
      READ(10,*)CELL,YEAR
C
C VECTORS VNEWSN, VOLDSN AND VSOIL CONTAIN THE PHYSICAL
C PROPERTIES OF NEW SNOW, OLD SNOW AND SOIL RESPECTIVELY.
C VECTOR(1,1)= 0.0
C VECTOR(1,2)= SNOW/SOIL THERMAL DIFFUSIVITY, cm2min-1
C VECTOR(1,3)= SNOW/SOIL HEAT CONDUCTIVITY, calcm-2min-1.K-1
C VECTOR(1,4)= SNOW/SOIL EMISSIVITY, DECIMAL
C VECTOR(1,5)= SNOW/SOIL ALBEDO, DECIMAL
C VECTOR(1,6)= SNOW/SOIL DENSITY, gcm-3
C
      READ(10,*)((VNEWSN(I,J),J=1,6),I=1,1)
      READ(10,*)((VOLDSN(I,J),J=1,6),I=1,1)
      READ(10,*)((VSOIL(I,J),J=1,6),I=1,1)
      READ(10,*)PRESS,NCLOUD,ZA
      READ(10,*)SLOPE1,SURFC1,DAY1,LAT
      READ(10,*)ILAPSE
      READ(10,*)IVEG
      READ(10,*)SNDP1
C
C IVEG DETERMINES WHICH VEGETATION DATA FILE IS USED:
C IVEG=1, CONIF.DAT (CONIFEROUS DATA)
C IVEG=2, DECID.DAT (DECIDUOUS DATA)
```

```
C IVEG=3, MIX.DAT (MIXED DATA)
C IVEG=0, NO VEGETATION DATA FILE IS USED, THE VEGETATION IS
C MODELLED AS PASTURE (OPEN) AND CLEARCUT.
C ILAPSE DETERMINES WHICH ELEVATION DATA FILE IS USED TO
C MODIFY THE AIR TEMPERATURES WITH LAPSE RATE.  THE PRESENT
C USE OF ILAPSE REFERS SOLELY TO THE APPLICATION OF SNOMO.F TO
C THE W3 CATCHMENT.
C ILAPSE=0, ELEVATION BAND 1500-2000FT.  THIS IS THE ELEVATION
C BAND OF THE METEOROLOGICAL STATION THAT PROVIDES THE INPUT
C DATA, THEREFORE NO CHANGES ARE MADE TO THE AIR TEMPERATURES.
C ILAPSE=1, ELEVATION BAND 1000-1500FT.  THIS INCREASES THE
C MAX. AIR TEMP. BY 2°F AND THE MIN. BY 1°F.
C
      IF(IVEG.EQ.1)THEN
      READ(11,*)SIGF,STATE,EPF,ALBEDO,HFOL
      ELSE
        IF(IVEG.EQ.2)THEN
        READ(13,*)SIGF,STATE,EPF,ALBEDO,HFOL
          ELSE
          IF(IVEG.EQ.3)THEN
          READ(14,*)SIGF,STATE,EPF,ALBEDO,HFOL
          END IF
        END IF
      END IF
      IF(ILAPSE.GT.0)THEN
      READ(12,*)TMAX,TMIN
      END IF
      READ(10,*)CRITDP
      READ(10,*)SOILDP,SOILTP,SSOLTP
      READ(10,*)N
C
C N= NUMBER OF DAYS TO BE MODELLED IE. NO. OF DAYS IN DATA FILE
C MINUS ONE.
C DAILY METEOROLOGICAL DATA.
C XXX(1,8)= JULIAN DATE
C XXX(1,1)= OBSERVATION TIME, 24HR CLOCK
C YYY(1,1)= MINIMUM AIR TEMPERATURE, °C
C YYY(1,9)= MAXIMUM AIR TEMPERATURE, °C
C YYY(1,2)= RELATIVE HUMIDITY, %
C YYY(1,3)= CLOUD COVER, 0-1
C YYY(1,6)= WIND SPEED, m/s
C YYY(1,7)= PRECIPITATION, mm WATER
C
      READ(10,*)XXX(1,8),XXX(1,1),YYY(1,1),YYY(1,9),YYY(1,2),
     & YYY(1,3),YYY(1,6),YYY(1,7)
      READ(10,*)XXX(2,8),XXX(2,1),YYY(2,1),YYY(2,9),YYY(2,2),
     & YYY(2,3),YYY(2,6),YYY(2,7)
C
C SIMPLE MODIFICATION OF AIR TEMPERATURES FOR LAPSE RATE
      IF(ILAPSE.EQ.0)THEN
      GOTO 5
      ELSE
```

```
C CONVERT °C TO °F
       YYY(1,1)=((YYY(1,1)*9.0)/5.0)+32.0
       YYY(1,9)=((YYY(1,9)*9.0)/5.0)+32.0
       YYY(2,1)=((YYY(2,1)*9.0)/5.0)+32.0
       YYY(2,9)=((YYY(2,9)*9.0)/5.0)+32.0
         IF(ILAPSE.EQ.1)THEN
         YYY(1,1)=YYY(1,1)+TMIN
         YYY(1,9)=YYY(1,9)+TMAX
         YYY(2,1)=YYY(2,1)+TMIN
         YYY(2,9)=YYY(2,9)+TMAX
         ELSE
         YYY(1,1)=YYY(1,1)-TMIN
         YYY(1,9)=YYY(1,9)-TMAX
         YYY(2,1)=YYY(2,1)-TMIN
         YYY(2,9)=YYY(2,9)-TMAX
         END IF
C CONVERT °F TO °C
       YYY(1,1)=((YYY(1,1)-32.0)/9.0)*5.0
       YYY(1,9)=((YYY(1,9)-32.0)/9.0)*5.0
       YYY(2,1)=((YYY(2,1)-32.0)/9.0)*5.0
       YYY(2,9)=((YYY(2,9)-32.0)/9.0)*5.0
       END IF
C
C THE SNOWDEPTH AND THE PHYSICAL PROPERTIES OF THE
C SNOWPACK ARE HELD IN THE MATRICES DEPMX1, DEPMX2
C (HOLDING THE SNOWDEPTH AND CORRESPONDING TEMPERATURE)
C AND THKMX1, THKMX2 (HOLDING THE THICKNESS OF THE LAYERS
C OF THE PACK AND THE CORRESPONDING PHYSICAL PROPERTIES,
C IE. VNEWSN OR VOLDSN).  THE NUMBERS 1 AND 2 REFER TO
C EITHER A 1- OR 2-LAYERED PACK, FOR A 1-LAYERED PACK
C NOMATL=1 AND NIPTS=2, FOR A 2-LAYERED PACK NOMATL=2,
C NIPTS=3.
C SET 2-LAYER SNOW THICKNESS MATRIX TO ZERO
C SET 2-LAYER DEPTH MATRIX TO ZERO
C
5      DO 20 I=1,2
        DO 10 J=1,6
        THKMX2(I,J)=0.0
10      CONTINUE
20     CONTINUE
       DO 40 I=1,3
        DO 30 J=1,2
        DEPMX2(I,J)=0.0
30      CONTINUE
40     CONTINUE
C
C SET CONTROLS TO ZERO
C WRITE HEADER FOR RESULTS FILE
C
       KONTRL=0
       SNVOL=0.0
       DEPTH=0.0
```

```
      K1=0
      K2=0
      K25=0
      WRITE(9,*)'CELL NO.:',CELL
      WRITE(9,*)'YEAR:',YEAR
      WRITE(9,*)'JULIAN     SNOWDEPTH       SNOWMELT      SNOWFALL
     & DENSITY  RAIN-ON-SNOW'
      WRITE(9,*)' DATE        (CM)    (CM SNOW) (MM WATER)  (CM)
     & (G/M**3) (1=YES, 0=NO)'
C
C DAILY CALCULATION LOOP
C
      DO 5001 L=1,N
       K1=K1+1
       K30=0
       KELVIN=YYY(1,1)+273.15
       PPTN=YYY(1,7)
       AIRTP=YYY(1,1)
       DDATE=XXX(1,8)
       TIME2=XXX(2,1)
C
C LOGIC STRUCTURE TO INITIALISE SNOWDEPTH
C
       IF(K3.EQ.1)THEN
       K2=0
       GOTO 57
       ELSE
         IF(PPTN.GT.0.0.AND.AIRTP.LT.0.0)THEN
         SNPPTN=(PPTN/VNEWSN(1,6))/10
         END IF
       END IF
       IF(K1.EQ.1)THEN
       K2=0
       SNPPTN=SNDP1
       END IF
       DEPTH=SNPPTN+DEPTH
       IF(DEPTH.GE.CRITDP)THEN
         IF(DEPTH.GT.CRITDP)THEN
         NOMATL=2
         NIPTS=3
         DEPMX2(1,1)=0.0
         DEPMX2(1,2)=AIRTP
         DEPMX2(2,1)=5.0
         DEPMX2(2,2)=AIRTP
         DEPMX2(3,1)=SNPPTN
         DEPMX2(3,2)=SSOLTP
         XSNTP=((DEPMX2(1,2)+DEPMX2(3,2))/2)+273.15
         DO 53 J=1,6
          THKMX2(1,J)=VNEWSN(1,J)
          THKMX2(2,J)=VOLDSN(1,J)
53       CONTINUE
         THKMX2(1,1)=5.0
```

```
        THKMX2(2,1)=SNPPTN-5.0
        ELSE
        NOMATL=1
        NIPTS=2
        DEPMX1(1,1)=0.0
        DEPMX1(1,2)=AIRTP
        DEPMX1(2,1)=DEPTH
        DEPMX1(2,2)=SSOLTP
        XSNTP=((DEPMX1(1,2)+DEPMX1(2,2))/2)+273.15
        DO 54 J=1,6
         THKMX1(1,J)=VNEWSN(1,J)
54      CONTINUE
        THKMX1(1,1)=DEPTH
        END IF
       ISNOW=ISNOW+1
       K25=0
       K3=1
       K2=1
       GOTO 57
       ELSE
       NOMATL=1
       NIPTS=2
       DO 56 J=1,6
        THKMX1(1,J)=VSOIL(1,J)
56     CONTINUE
       THKMX1(1,1)=SOILDP
       DEPMX1(1,1)=0.0
       DEPMX1(1,2)=AIRTP
       DEPMX1(2,1)=SOILDP
       DEPMX1(2,2)=SOILTP
       K3=0
       K2=0
       END IF
C
C CALL SUBROUTINE CSFRQ, TO CALCULATE SFRQ
C
57     CALL CSFRQ(I,N)
C
C SET DEPTH MATRICES AND VARIABLES TO ZERO
C
       IF(NOMATL.EQ.1)THEN
       DO 59 I=1,3
        DO 58 J=1,2
        DEPMX2(I,J)=0.0
58      CONTINUE
59     CONTINUE
       ELSE
       DO 61 I=1,2
        DO 60 J=1,2
        DEPMX1(I,J)=0.0
60      CONTINUE
61     CONTINUE
```

```
      END IF
      K10=0
      AVSTP=0.0
      STP=0.0
      AVSOL=0.0
      AVGBR=0.0
      AVABSR=0.0
      AVATER=0.0
      AVHTER=0.0
      AVDTER=0.0
      AVBTTP=0.0
      BOTTP=0.0
C
C CALL SUBROUTINE TSTM, TO CALCULATE THE SHORTWAVE, LONGWAVE, LATENT
C HEAT AND SENSIBLE HEAT EXCHANGES AT THE SURFACE OF THE SNOWPACK AND
C HEAT TRANSPORT THROUGH THE PACK.  IN SNOMO TSTM CAN MODEL THESE
C EXCHANGES FOR EITHER SNOW OR SOIL.
C
      CALL TSTM(I,'Y','N',K10,AVSTP,AVSOL,AVGBR,AVABSR,AVATER,
     & AVHTER,AVDTER,K2,AVBTTP,TGBR,TSOL,TABSOR,
     & TATERM,THTERM,TDTERM)
C
C PROGRAM CONTINUES IF SNOW WAS MODELLED BY TSTM, JUMPS TO THE NEXT DAY
C IF SOIL WAS MODELLED
C
      IF(K3.EQ.0)THEN
      GOTO 9000
      ELSE
      K3=1
      END IF
C
C CALL SUBROUTINE CMELT, TO CALCULATE THE MELT RATE.  THE ENERGY
C INTRODUCED TO THE PACK BY RAIN (PTERM) IS NOT INCLUDED AT THIS STAGE
C MELT RATE IS CALCULATED IN CM OF SNOW AND MM OF WATER EQUIVALENT.
C
      PTERM=0.0
      CALL CMELT(I,N,NETRAD,PTERM,TSOL,TGBR,TABSOR,
     & TATERM,THTERM,TDTERM,PPTN,DENSN,MRWE,MRSN,GTERM,DENW,DEPTH,
     & AVSTP,AVBTTP,XSNTP,SPHTI,K30)
      IRAIN=0
C
C CALL SUBROUTINE RAINMP, TO CALCULATE THE ENERGY INTRODUCED TO THE
C MELTING PACK BY RAIN, IF RAIN OCCURED.  THE MELT RATE IS RECALCULATED.
C
      IF(PPTN.GT.0.0.AND.AIRTP.GT.0.0)THEN
        IF(MRWE.GT.0.0)THEN
        IRAIN=1
        CALL RAINMP(I,N,PPTN,PTERM,DENW,K30)
        CALL CMELT(I,N,NETRAD,PTERM,TSOL,TGBR,TABSOR,
     &  TATERM,THTERM,TDTERM,PPTN,DENSN,MRWE,MRSN,GTERM,DENW,
     &  DEPTH,AVSTP,AVBTTP,XSNTP,SPHTI,K30)
        END IF
```

```
        END IF
C
C CALCULATION OF SNOWFALL IF NOT FIRST ITERATION OR SOIL MODELLED
C IN THE PREVIOUS ITERATION.
C
        IF(AVSTP.GT.0.0)THEN
        AVSTP=0.0
        END IF
        IF(K2.EQ.0)THEN
          IF(PPTN.GT.0.0.AND.AIRTP.LT.0.0)THEN
          SNPPTN=(PPTN/VNEWSN(1,6))/10
          K25=0
          ELSE
          SNPPTN=0.0
          K25=K25+1
          END IF
        END IF
C
C LOGIC STRUCTURE TO ALLOW FOR THE EFFECTS OF SNOWFALL
C
        IF(K1.EQ.1)THEN
        DEPMX2(1,2)=AVSTP
        DEPMX2(3,2)=AVBTTP
        DEPMX2(2,2)=((DEPMX2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
        GOTO 3000
        END IF
        IF(SNPPTN.GT.0.0)THEN
          IF(NOMATL.EQ.1)THEN
            IF(THKMX1(1,2).EQ.VNEWSN(1,6))THEN
              IF(ISNOW.GT.0)THEN
              THKMX1(1,1)=THKMX1(1,1)+SNPPTN
              DEPTH=DEPTH+SNPPTN
              DEPMX1(2,1)=DEPTH
              DEPMX1(1,2)=AVSTP
              DEPMX1(2,2)=AVBTTP
              GOTO 4000
              ELSE
              WE1=(THKMX1(1,1)*10)*VNEWSN(1,6)
              DEPTH1=(WE1/VOLDSN(1,6))/10
              NOMATL=2
              NIPTS=3
              DO 70 J=1,6
               THKMX2(1,J)=VNEWSN(1,J)
               THKMX2(2,J)=VOLDSN(1,J)
70            CONTINUE
              THKMX2(1,1)=SNPPTN
              THKMX2(2,1)=DEPTH1
              DEPTH=SNPPTN+DEPTH1
              DEPMX2(1,2)=AVSTP
              DEPMX2(3,2)=AVBTTP
              DEPMX2(3,1)=DEPTH
              DEPMX2(2,1)=THKMX2(1,1)
```

```
            DEPMX2(2,2)=((DEPMX2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
            GOTO 3000
            END IF
          ELSE
          NOMATL=2
          NIPTS=3
          DO 80 J=1,6
           THKMX2(1,J)=VNEWSN(1,J)
           THKMX2(2,J)=VOLDSN(1,J)
80        CONTINUE
          THKMX2(1,1)=SNPPTN
          THKMX2(2,1)=DEPTH
          DEPTH=DEPTH+SNPPTN
          DEPMX2(1,2)=AVSTP
          DEPMX2(3,2)=AVBTTP
          DEPMX2(3,1)=DEPTH
          DEPMX2(2,1)=THKMX2(1,1)
          DEPMX2(2,2)=((DEPMX2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
          GOTO 3000
          END IF
        ELSE
          IF(ISNOW.GT.0)THEN
          THKMX2(1,1)=THKMX2(1,1)+SNPPTN
          DEPTH=DEPTH+SNPPTN
          DEPMX2(3,1)=DEPTH
          DEPMX2(2,1)=THKMX2(1,1)
          DEPMX2(2,2)=AVSTP
          DEPMX2(3,2)=AVBTTP
          DEPMX2(2,2)=((DEPMX2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
          GOTO 3000
          ELSE
          WE1=(THKMX2(1,1)*10)*VNEWSN(1,6)
          DEPTH1=(WE1/VOLDSN(1,6))/10
          THKMX2(2,1)=THKMX2(2,1)+DEPTH1
          THKMX2(1,1)=SNPPTN
          DEPTH=THKMX2(2,1)+THKMX2(1,1)
          DEPMX2(3,1)=DEPTH
          DEPMX2(2,1)=THKMX2(1,1)
          DEPMX2(1,2)=AVSTP
          DEPMX2(3,2)=AVBTTP
          DEPMX2(2,2)=((DEPMX2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
          GOTO 3000
          END IF
        END IF
      ELSE
        IF(NOMATL.EQ.1)THEN
          IF(THKMX1(1,2).EQ.VNEWSN(1,6))THEN
            IF(ISNOW.GE.1)THEN
            DEPMX1(1,2)=AVSTP
            DEPMX1(2,2)=AVBTTP
            GOTO 4000
            ELSE
```

```
              WE1=(THKMX1(1,1)*10)*VNEWSN(1,6)
              DEPTH1=(WE1/VOLDSN(1,6))/10
              DEPTH=DEPTH1
              DO 250 J=1,6
               THKMX1(1,J)=VOLDSN(1,J)
 250          CONTINUE
              THKMX1(1,1)=DEPTH
              DEPMX1(1,2)=AVSTP
              DEPMX1(2,2)=AVBTTP
              DEPMX1(2,1)=DEPTH
              GOTO 4000
              END IF
            ELSE
            DEPMX1(1,2)=AVSTP
            DEPMX1(2,2)=AVBTTP
            GOTO 4000
            END IF
          ELSE
            IF(ISNOW.GT.0)THEN
            DEPMX2(1,2)=AVSTP
            DEPMX2(3,2)=AVBTTP
            DEPMX2(2,2)=((DEPMX2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
            GOTO 3000
            ELSE
            WE1=(THKMX2(1,1)*10)*VNEWSN(1,6)
            DEPTH1=(WE1/VOLDSN(1,6))/10
            DEPTH=DEPTH1+THKMX2(2,1)
            NOMATL=1
            NIPTS=2
            DO 350 J=1,6
             THKMX1(1,J)=VOLDSN(1,J)
 350        CONTINUE
            THKMX1(1,1)=DEPTH
            DEPMX1(1,2)=AVSTP
            DEPMX1(2,2)=AVBTTP
            DEPMX1(2,1)=DEPTH
            GOTO 4000
            END IF
          END IF
        END IF
C
C LOGIC STRUCTURE TO ALLOW FOR THE EFFECTS OF SNOWMELT
C ON A 2-LAYER PACK.
C
3000    IF(DEPTH.LE.5.0)THEN
        GOTO 5002
        END IF
C*************************************************************************
C OPTION 3-MASS CONSERVATION ROUTINE.
C IF OPTION 3 REQUIRED INSERT MASS CONSERVATION ROUTINE TO REPLACE
C ALL CODE BETWEEN THE ********LINES.
C
```

```
3001    IF(MRSN.GE.DEPTH)THEN
        GOTO 5002
        ELSE
          IF(MRSN.LE.0.0)THEN
          DEPMX2(1,2)=AVSTP
          DEPMX2(3,2)=AVBTTP
          DEPMX2(3,1)=DEPTH
          DEPMX2(2,1)=THKMX2(1,1)
          DEPMX2(2,2)=((DEPMX2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
          THKMX2(2,1)=DEPTH-THKMX2(1,1)
          GOTO 3500
          ELSE
            IF(MRSN.GE.THKMX2(1,1))THEN
            NOMATL=1
            NIPTS=2
            DO 400 J=1,6
             THKMX1(1,J)=VOLDSN(1,J)
400         CONTINUE
            DEPTH=DEPTH-MRSN
            THKMX1(1,1)=DEPTH
            DEPMX1(1,2)=AVSTP
            DEPMX1(2,2)=AVBTTP
            DEPMX1(2,1)=THKMX1(1,1)
            ELSE
            THKMX2(1,1)=THKMX2(1,1)-MRSN
            DEPTH=THKMX2(1,1)+THKMX2(2,1)
            DEPMX2(1,2)=AVSTP
            DEPMX2(3,2)=AVBTTP
            DEPMX2(3,1)=DEPTH
            DEPMX2(2,1)=THKMX2(1,1)
            DEPMX2(2,2)=((DEPMX2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
            END IF
3500        GOTO 5000
          END IF
        END IF
C
C LOGIC STRUCTURE TO ALLOW FOR THE EFFECTS OF SNOWMELT
C ON A 1-LAYER PACK.
C
4000    IF(DEPTH.LE.5.0)THEN
        GOTO 5002
        END IF
4001    IF(MRSN.GE.DEPTH)THEN
        GOTO 5002
        ELSE
          IF(MRSN.LE.0.0)THEN
          DEPMX1(1,2)=AVSTP
          DEPMX1(2,2)=AVBTTP
          DEPMX1(2,1)=THKMX1(1,1)
          ELSE
          DEPTH=DEPTH-MRSN
          THKMX1(1,1)=DEPTH
```

```
          DEPMX1(1,2)=AVSTP
          DEPMX1(2,2)=AVBTTP
          DEPMX1(2,1)=THKMX1(1,1)
          END IF
        END IF
C
C IF TOP LAYER OF 2-LAYER PACK IS <1CM THICK THEN PACK IS
C CONVERTED INTO 1-LAYER PACK.
C
5000    IF(NOMATL.EQ.2.AND.THKMX2(1,1).LT.1.0)THEN
        DEPTH=THKMX2(1,1)+THKMX2(2,1)
        NOMATL=1
        NIPTS=2
        DO 450 J=1,6
         THKMX1(1,J)=VOLDSN(1,J)
450     CONTINUE
        THKMX1(1,1)=DEPTH
        DEPMX1(2,1)=DEPTH
        DEPMX1(1,2)=AVSTP
        DEPMX1(2,2)=AVBTTP
        END IF
C
C MELTRATE CANNOT BE NEGATIVE.
C
        IF(MRSN.LT.0.0)THEN
        MRSN=0.0
        END IF
        IF(MRWE.LT.0.0)THEN
        MRWE=0.0
        END IF
550     FORMAT(6F6.2)
555     FORMAT(2F6.2)
C***********************************************************************
C END OF OPTION 3 CODE INSERTION.
C
C
C READ IN NEXT DAILY DATA LINE, SHIFTING EXISTING BOTTOM
C DATA LINE TO THE TOP.  EXIT PROGRAM IF LAST DATA LINE
C REACHED.
C
9000   YYY(2,6)=YYY(2,6)/100.0
       YYY(2,2)=YYY(2,2)*100
       XXX(1,8)=XXX(2,8)
       XXX(1,1)=TIME2
       YYY(1,1)=YYY(2,1)
       YYY(1,2)=YYY(2,2)
       YYY(1,9)=YYY(2,9)
       YYY(1,3)=YYY(2,3)
       YYY(1,6)=YYY(2,6)
       YYY(1,7)=YYY(2,7)
       XXX(2,8)=0
       XXX(2,1)=0
```

```
      YYY(2,1)=0
      YYY(2,9)=0
      YYY(2,2)=0
      YYY(2,3)=0
      YYY(2,6)=0
      YYY(2,7)=0
      NKONT=N-KONTRL
      IF(NKONT.EQ.1)THEN
      GOTO 5002
      END IF
      YYY(1,1)=YYY(1,1)-273.15
      YYY(1,9)=YYY(1,9)-273.15
      READ(10,*)XXX(2,8),XXX(2,1),YYY(2,1),YYY(2,9),YYY(2,2),
     & YYY(2,3),YYY(2,6),YYY(2,7)
C
C CONVERT AIR TEMPERATURE FOR LAPSE RATE
C
      IF(ILAPSE.EQ.0)THEN
      GOTO 90
      ELSE
C CONVERT °C TO °F
      YYY(2,1)=((YYY(2,1)*9.0)/5.0)+32.0
      YYY(2,9)=((YYY(2,9)*9.0)/5.0)+32.0
        IF(ILAPSE.EQ.1)THEN
        YYY(2,1)=YYY(2,1)+TMIN
        YYY(2,9)=YYY(2,9)+TMAX
        ELSE
        YYY(2,1)=YYY(2,1)-TMIN
        YYY(2,9)=YYY(2,9)-TMAX
        END IF
C CONVERT °F TO °C
      YYY(2,1)=((YYY(2,1)-32.0)/9.0)*5.0
      YYY(2,9)=((YYY(2,9)-32.0)/9.0)*5.0
      END IF
C
C REINITIALISATION OF CERTAIN VARIABLES, WRITE OUT RESULTS.
C
90    IF(K2.EQ.0)THEN
        IF(SNPPTN.GT.0.0)THEN
        ISNOW=ISNOW+1
        ELSE
        ISNOW=0
        END IF
      END IF
      AIRTP=YYY(1,1)
      KELVIN=YYY(1,1)+273.15
      PPTN=YYY(1,7)
      DDATE=XXX(1,8)
      KONTRL=KONTRL+1
      SNOW=SNPPTN
      SNPPTN=0.0
      WRITE(9,333)DDATE-1,DEPTH,MRSN,MRWE,SNOW,DENSN,IRAIN
```

```
333     FORMAT(F6.2,5X,F6.2,4X,F6.2,4X,F6.2,4X,F6.2,7X,F6.2,5X,I3)
5001    CONTINUE
5002    WRITE(9,*)'PROGRAM TERMINATION'
        STOP
        END
C
C ------------------------------------------------------------
```

```
C
C SUBROUTINE CMELT
C ----------------
C THIS CALCULATES THE MELTRATE IN CM OF SNOW AND MM OF WATER EQUIVALENT.
C THE DENSITY OF THE SNOWPACK IS CALCULATED IF THE PACK IS A 2-LAYERED
C PACK.  MELT IS CALCULATED USING THE SNOW ENERGY-BUDGET.  MOST OF
C THE COMPONENTS OF THE SNOW ENERGY-BUDGET ARE CALCULATED BY TSTM, THE
C EXCEPTIONS ARE PTERM AND DELQS.  THE ENERGY UNITS ARE MJm^-2day^-1.
C
      SUBROUTINE CMELT(I,N,NETRAD,PTERM,TSOL,TGBR,TABSOR,
     & TATERM,THTERM,TDTERM,PPTN,DENSN,MRWE,MRSN,GTERM,DENW,DEPTH,
     & AVSTP,AVBTTP,XSNTP,SPHTI,K30)
      COMMON/MATRX2/DEPMX1(2,2),DEPMX2(3,2)
      COMMON/MATRX3/THKMX1(1,6),THKMX2(2,6)
      COMMON/TSTM2/NOMATL,NIPTS
      REAL LHEATF,NETRAD,MRWE,MRSN,DEPTH,DENSN,A,B,C,D,
     & XSNTP1,DELQS,DELRWE,DELRSN,XSNTP
      DATA LHEATF,HCAPW,HCAPSN/0.334,4.21,2.09/
      GTERM=0.0
C
C CALCULATION OF THE DENSITY OF SNOW
C
      IF(NOMATL.EQ.1)THEN
      DENSN=THKMX1(1,6)
      ELSE
      A=THKMX2(1,1)/DEPTH
      B=THKMX2(2,1)/DEPTH
      C=A*THKMX2(1,6)
      D=B*THKMX2(2,6)
      DENSN=C+D
      END IF
C
C CALCULATION OF DELQS IN Jm^-2day^-1, THEN CONVERTED TO MJm^-2dy^-1
C
      IF(K30.EQ.1)THEN
      K30=0
      GOTO 10
      ELSE
      XSNTP1=XSNTP
      XSNTP=((AVSTP+AVBTTP)/2)+273.15
      DELQS=((DEPTH*0.01)*(DENSN*1000))*((SPHTI*XSNTP)-
     & (SPHTI*XSNTP1))
      END IF
C
C CALCULATION OF THE ENERGY-BUDGET OF THE SNOWPACK AND THE MELT RATE.
C MULTIPLY MRWE BY 1000, SO THAT RESULT IS IN MM WATER.
C MULTIPLY MRSN BY 100, SO THAT RESULT IS IN CM SNOW.
C
10    NETRAD=TSOL-(TSOL-TABSOR)+TATERM-TGBR
      DELQM=NETRAD+TDTERM+THTERM+GTERM+PTERM-DELQS
      DELRWE=(DELQM/(LHEATF*DENW))*1000
      DELRSN=(DELQM/(LHEATF*(DENSN*1000)))*100
```

```
      MRWE=DELRWE
      MRSN=DELRSN
      RETURN
      END
C
C ------------------------------------------------------------------
```

```
C
C SUBROUTINE RAINMP
C -----------------
C CALCULATES THE ENERGY INPUT TO THE PACK BY RAIN FALLING ON
C A MELTING PACK AT 0OC.  THE EQUATION IS TAKEN FROM MALE &
C GRAY (1981).  THE UNITS ARE MJm^-2dy^-1.
C
      SUBROUTINE RAINMP(I,N,PPTN,PTERM,DENW,K30)
      COMMON/RAIN/AIRTP
      REAL PTERM
      DATA LHEATF,HCAPSN,HCAPW/0.334,2.09,4.21/
      DATA SPHTW/4.18/
      PTERM=(DENW*SPHTW*AIRTP*PPTN)/1000
      PTERM=PTERM/1000
      K30=1
      RETURN
      END
C
C ---------------------------------------------------------------
```

```
C SUBROUTINE CSFRQ
C ----------------
C CALCULATES SFRQ, THE VERTICAL GRID SPACING IN EACH
C COMPUTATIONAL LAYER.
C
      SUBROUTINE CSFRQ(I,N)
      COMMON/MATRX3/THKMX1(1,6),THKMX2(2,6)
      COMMON/VECTOR/VNEWSN(1,6),VOLDSN(1,6)
      COMMON/TSTM2/NOMATL,NIPTS
      COMMON/VEGI/IVEG,SIGF,STATE,EFF,FOLA,HFOL
      COMMON/SFRQ/SFRQ(6)
      REAL SFRQ1,SFRQ2
      DATA TOTTIM,TFRQ,TPRNT/1,1.0,60.0/
C
C CALCULATION OF SFRQ FOR LAYER 1
C
      IF(NOMATL.EQ.1)THEN
      SFRQ1=(THKMX1(1,1))/2
      ELSE
      SFRQ1=(THKMX2(1,1))/2
      END IF
100   IF(SFRQ1.LE.5.0)THEN
      GOTO 200
      ELSE
        IF(SFRQ1.LE.10.0)THEN
        GOTO 200
        ELSE
        SFRQ1=SFRQ1/2
        GOTO 100
        END IF
      END IF
200   SFRQ(1)=SFRQ1
C
C CALCULATION OF SFRQ FOR LAYER 2, IF NECESSARY
C
      IF(NOMATL.EQ.2)THEN
      SFRQ2=THKMX2(2,1)/2
300     IF(SFRQ2.LE.5.0)THEN
        GOTO 400
        ELSE
          IF(SFRQ2.LE.10.0)THEN
          GOTO 400
          ELSE
          SFRQ2=SFRQ2/2
          GOTO 300
          END IF
        END IF
400   SFRQ(2)=SFRQ2
      END IF
C
C CALCULATION OF TIMESTEP ENSURING NUMERICAL STABILITY.
C
```

```
      IF(NOMATL.EQ.1)THEN
      TIMSP1=0.5*(SFRQ(1)*SFRQ(1)/VNEWSN(1,2))
      ELSE
      TIMSP1=0.5*(SFRQ(1)*SFRQ(1)/VNEWSN(1,2))
      TIMSP2=0.5*(SFRQ(2)*SFRQ(2)/VOLDSN(1,2))
      TIMSP1=MIN(TIMSP1,TIMSP2)
      END IF
      ITIME=INT(TIMSP1)
      IF(ITIME.EQ.0)ITIME=1
      IF(ITIME.GT.5)ITIME=5
      IF(IVEG.EQ.1)ITIME=1
      TFRQ=REAL(ITIME)
      RETURN
      END
C
C -----------------------------------------------------------------
```

```
C
C SUBROUTINE TSTM
C ---------------
C CALCULATES THE SHORTWAVE, LONGWAVE, LATENT HEAT AND SENSIBLE HEAT
C EXCHANGES OVER THE SNOWPACK OR SOIL SURFACE, AND THE HEAT TRANSPORT
C THROUGH THE SOIL OR SNOW.  TSTM HAS BEEN CONVERTED INTO A SUBROUTINE
C FROM BALICK ET.AL. (1981a & b).  THE CONVERSION OF TSTM AND INCLUSION
C OF VEGIE WAS AIDED BY DR. RANDY SCOGGINS (WES).  VEGETATED SURFACES
C ARE MODELLED USING THE SUBMODEL VEGIE.  TSTM WAS ORIGINALLY THE TERRAIN
C SURFACE TEMPERATURE MODEL AND ITS FUNCTION WAS TO PREDICT SURFACE
C TEMPERATURE.
C
C
C
      SUBROUTINE TSTM(I,AN1,AN,K10,AVSTP,AVGBR,AVSOL,AVABSR,
     & AVATER,AVHTER,AVDTER,K2,AVBTTP,TGBR,TSOL,TABSOR,TATERM,
     & THTERM,TDTERM)
C
C INITIALISATION, DECLARATION AND DATA STATEMENTS
C
      INTEGER OUTCD
      DIMENSION DATMX(100,10)
      DIMENSION RHOC(6),MAX(10),DEPTH(450),FMM(30,10),BBB(30,10)
      DIMENSION TITLE(7)
      DIMENSION NX(6),ATF(2),FEB(2)
      DIMENSION RR(6),INTR(7)
      DIMENSION THK(6),ALPH(6),FK(6),STOR(7,450),STABN(6)
      REAL KTEMPG,KTEMPA,LAT,ACL(8),BCL(8),M,KSQ,BOTTP,WET,
     & ISOL,IGBR,IABSOR,IATERM,IHTERM,IDTERM,ISURFG,IREFRA,
     & SLOPE,SURFAC,CLR(8)
      CHARACTER HEADER*72,AN*1,AN1*1
      COMMON/MATRX1/XXX(30,10),YYY(30,10)
      COMMON/MATRX2/DEPMX1(2,2),DEPMX2(3,2)
      COMMON/MATRX3/THKMX1(1,6),THKMX2(2,6)
      COMMON/TSTM1/PRESS,NCLOUD,ZA,SLOPE1,SURFC1,DAY,LAT
      COMMON/TSTM2/NOMATL,NIPTS
      COMMON/VEGI/IVEG,SIGF,STATE,EPF,ALBEDO,HFOL
      COMMON/SFRQ/SFRQ(6)
      DATA TOTTIM,TFRQ,TPRNT/1,1.0,60.0/
      DATA CLR/0.04,0.08,0.17,0.20,0.22,0.24,0.24,0.25/
      DATA OUTCD/0/
      DATA ACL/82.2,87.1,52.5,39.0,34.7,23.8,11.2,15.4/
      DATA BCL/.079,.148,.112,.063,.104,.159,-.167,.028/
      DATA SIGMA,PI,AC,BC/8.12E-11,3.141593,17.269,35.86/
      DATA CC/0.261/
      DATA LAST,G,KSQ,CP/2,980.0,0.16,0.24/
C
C STATEMENT FUNCTIONS FOR USE IN VEGETATION SECTION
C
      E(T)=RH*6.108*EXP(AC*(T-273.15)/(T-BC))
      ESAT(T)=6.108*EXP(AC*(T-273.15)/(T-BC))
      Q(T)=0.622/(PRESS/E(T)-.378)
```

```
      QSAT(T)=0.622/(PRESS/ESAT(T)-.378)
C
C CONVERSION OF VARIABLES PASSED FROM MAIN PROGRAM INTO FORM
C USED IN TSTM.  1 OR 2-LAYERED SNOWPACK USED.
C
      IFLAG2=0
      IRETRN=0
      IPRNT=0
      SUN=0.0
      IF(NOMATL.EQ.1)THEN
      XXX(1,5)=DEPMX1(1,1)
      YYY(1,5)=DEPMX1(1,2)
      XXX(2,5)=DEPMX1(2,1)
      YYY(2,5)=DEPMX1(2,2)
      THK(1)=THKMX1(1,1)
      ALPH(1)=THKMX1(1,2)
      FK(1)=THKMX1(1,3)
      EPSN=THKMX1(1,4)
      SMALLA=(1-THKMX1(1,5))
      ELSE
      XXX(1,5)=DEPMX2(1,1)
      YYY(1,5)=DEPMX2(1,2)
      XXX(2,5)=DEPMX2(2,1)
      YYY(2,5)=DEPMX2(2,2)
      XXX(3,5)=DEPMX2(3,1)
      YYY(3,5)=DEPMX2(3,2)
      THK(1)=THKMX2(1,1)
      THK(2)=THKMX2(2,1)
      ALPH(1)=THKMX2(1,2)
      ALPH(2)=THKMX2(2,2)
      FK(1)=THKMX2(1,3)
      FK(2)=THKMX2(2,3)
      EPSN=THKMX2(1,4)
      SMALLA=(1-THKMX2(1,5))
      END IF
C-----------------------------------------------------------------
C     INITIALIZE-VARIABLES-AND-CONSTANTS
99996 ASSIGN 99994 TO I99995
      GO TO 99995
99994 CONTINUE
C-----------------------------------------------------------------
C     INPUT-DATA
      ASSIGN 99989 TO I99990
      GO TO 99990
C-----------------------------------------------------------------
C     PRINT-INPUT-DATA
99989 ASSIGN 99987 TO I99988
      IF(AN1.EQ.'Y')GO TO 99988
99987 CONTINUE
C-----------------------------------------------------------------
C     CALCULATE-TABLE-SLOPE-AND-INTERCEPT
99986 ASSIGN 99982 TO I99983
```

```
      GO TO 99983
C-----------------------------------------------------------
C     CALCULATE-SURFACE-AND-LAYER-TEMPERATURE
99982 CONTINUE
      ASSIGN 99980 TO I99981
      GO TO 99981
C-----------------------------------------------------------
99980 CONTINUE
      PPTN=(YYY(1,7)+YYY(2,7))/2
C
C CALCULATION OF DAILY TOTALS FOR THE ENERGY-BUDGET VARIABLES
C REQUIRED BY THE MAIN PROGRAM.
C
      SUMC2=0
      SUMC3=0
      SUMC4=0
      SUMC5=0
      SUMC6=0
      SUMC7=0
      SUMC8=0
      SUMC9=0
      DO 99 I=1,K10
      SUMC2=SUMC2+DATMX(I,2)
      SUMC3=SUMC3+DATMX(I,3)
      SUMC4=SUMC4+DATMX(I,4)
      SUMC5=SUMC5+DATMX(I,5)
      SUMC6=SUMC6+DATMX(I,6)
      SUMC7=SUMC7+DATMX(I,7)
      SUMC8=SUMC8+DATMX(I,8)
      SUMC9=SUMC9+DATMX(I,9)
99    CONTINUE
C
C CONVERT DAILY ENERGY TOTALS IN lyhr^-1 TO MJm^-2day^-1
C
      TGBR=SUMC3/24
      TSOL=SUMC4/24
      TABSOR=SUMC5/24
      TATERM=SUMC6/24
      TBTERM=SUMC7/24
      TDTERM=SUMC8/24
C
C CALCULATION OF MEAN DAILY ENERGY VALUES IN MJm^-2
C AND MEAN SURFACE AND BASAL TEMPERATURES (°C).
C
      AVSTP=SUMC2/K10
      AVGBR=(SUMC3/K10)/24
      AVSOL=(SUMC4/K10)/24
      AVABSR=(SUMC5/K10)/24
      AVATER=(SUMC6/K10)/24
      AVBTER=(SUMC7/K10)/24
      AVDTER=(SUMC8/K10)/24
      AVBTTP=SUMC9/K10
```

```
C
C RETURN TO MAIN PROGRAM
C
      WRITE(*,*)'NORMAL TERMINATION'
C-----------------------------------------------------------
C     STOP
      RETURN
C-----------------------------------------------------------
C-----------------------------------------------------------
99997 CONTINUE
C  FORMATS
 90    FORMAT(' BOTTOM BOUNDRY INDEX=',I3)
 92    FORMAT(' BOTTOM BOUNDRY TEMPERATURE=',F6.1,' DEG C')
 95    FORMAT(' BOTTOM BOUNDRY HEAT FLUX=',F6.1,'W/M**2')
 97    FORMAT(F11.2,F11.1,F13.2,F13.1,F8.2)
 120   FORMAT(A8,F6.1)
 140   FORMAT(F5.1,F10.1,F6.1,F12.1,F12.1,F13.1)
 145   FORMAT(F6.1,F7.1)
 150   FORMAT(F12.1,I12,F11.2)
 160   FORMAT(F11.2,F13.2,F8.1,F10.1)
 170   FORMAT(F9.4,F12.1)
 180   FORMAT(I7,F16.1,F11.0,F12.0)
C190   FORMAT(4X,F5.2,F6.1,2X,I8,I9,I11,I9,I9,I8)
 190   FORMAT(4X,F5.2,F6.1,F8.2,F8.2,F8.2,F8.2,F8.2,F8.2)
 260   FORMAT(9X,F8.1,F11.2,F9.2,F9.2,F8.2,F10.2,F8.2)
 200   FORMAT(F6.2,F8.2)
 210   FORMAT(I6,F11.1,F12.1,F14.2,F14.2)
 220   FORMAT(1H1)
 230   FORMAT(A72)
 240   FORMAT(4X,F7.2,3X,F5.0,5X,F6.2,10X,F6.2,9X,F7.2)
 250   FORMAT(6X,F6.1,13X,F4.1,12X,F5.1)
 310  FORMAT(11X,'TOTAL GRAYBODY  EFFECTIVE     GROUND   FOLIAGE',
    &          4X,'SOLAR')
 320  FORMAT(14X,'RADIANCE        TEMP',10X,'TEMP     TEMP'
    & ,4X,'INSOLATION')
 330  FORMAT(5X,'HR',7X,'(LANGLEYS)',9X,'(C)',11X,'(C)'
    & ,6X,'(C)   (LANGLEYS)')
 340  FORMAT(9X,'-----REFL-NREFL----REFL----NREFL',30(1H-))
 270  FORMAT(3X,F5.2,F8.2,F8.2,2X,F8.2,F8.2,F8.2,F8.2,F8.2,F8.2)
 350  FORMAT(57X,'SENSIBLE LATENT')
 360  FORMAT(5X,'HRS SURFACE  GRAYBODY   SOLAR     SURFACE  ATMOS',
    & ' IR   HEAT    HEAT')
 370   FORMAT(11X,'TEMP   RADIANCE INSOLATION   ABSORP  EMISSION',
    &   '    LOSS     FLUX')
 380  FORMAT(11X,'DEG C',23(1H-),'(LANGLEYS)',24(1H-))
 390  FORMAT(3X,'TIME',18X,'DEPTH, TEMPERATURE'/4X,'HR',21X,'CM',
    & 9X,'C'/2X,65(1H-))
  400 FORMAT(2H0 ,F5.2,4(3X,F5.1,' ',F5.2))
  410 FORMAT(10X,F5.1,1X,F5.2,3X,F5.1,1X,F5.2,3X,F5.1,1X,F5.2,
    & 3X,F5.1,1X,F5.2)
      GO TO I99997
C----------------------------------------------------------------
```

```
99995 CONTINUE
C     TO INITIALIZE-VARIABLES-AND-CONSTANTS
        BB=-2.4E-4
        MAX(1)=2
        MAX(2)=2
        MAX(3)=2
        MAX(4)=2
        MAX(5)=NIPTS
        MAX(6)=2
        MAX(7)=2
        MAX(8)=0
        MAX(9)=0
        MAX(10)=3
        IBUG=0
        IEOF=0
        GO TO I99995
C-------------------------------------------------------------
99990 CONTINUE
C   TO INPUT-DATA
C
C       INPUT-ATMOSPHERIC-SPECIFICATIONS
        ASSIGN 99978 TO I99979
        GO TO 99979
C
C       INPUT-SURFACE-ORIENTATION-SPECIFICATIONS
99978   ASSIGN 99976 TO I99977
        GO TO 99977
C
C     INPUT-HEAT-FLOW-CACULATION-CONTROLS
99976   ASSIGN 99974 TO I99975
        GO TO 99975
C
C     INPUT-INITIAL-TEMPERATURE-PROFILE
99974   ASSIGN 99972 TO I99973
        GO TO 99973
C
C     INPUT-TOP-SURFACE-CONSTSNTS
99972   ASSIGN 99970 TO I99971
        GO TO 99971
C
C     INPUT-LAYER-SPECIFICATIONS
99970   ASSIGN 99968 TO I99969
        GO TO 99969
C
C     INPUT-BOTTOM-BOUNDARY-DATA
99968   ASSIGN 99966 TO I99967
        GO TO 99967
C
C     INPUT-VEGETATION-PARAMETERS
99966   ASSIGN 99798 TO I99799
        GO TO 99799
C
```

```
99798  GO TO I99990
C-----------------------------------------------------------
99979  CONTINUE
C    TO INPUT-ATMOSPHERIC-SPECIFICATIONS
C
C      LINE   TIME    AIR TEMP RH  CLOUD COVER WIND SPEED,INSOLATION
C      NO.    HR     DEG C    %   (0-1)       M/3        CAL/CM**2-MIN
C
       XXX(2,1)=XXX(2,1)+2400*(XXX(2,8)-XXX(1,8))
  860  DO 99965 J=1,2
       IXXX=INT(XXX(J,1)/100.0)*100
       AXXX=(XXX(J,1) - REAL(IXXX))/60.0
       XXX(J,1)=REAL(IXXX)/100.0+AXXX
       XXX(J,7)=XXX(J,1)
       XXX(J,2)=XXX(J,1)
       XXX(J,3)=XXX(J,1)
       XXX(J,4)=XXX(J,1)
       XXX(J,6)=XXX(J,1)
       YYY(J,1)=YYY(J,1)+273.1
       YYY(J,9)=YYY(J,9)+273.15
       YYY(J,2)=YYY(J,2)*0.01
       YYY(J,6)=YYY(J,6)*100.0
       YYY(J,4)=YYY(J,4)/697.6
99965  CONTINUE
       XXX(3,10)=XXX(2,1)
       XXX(2,10)=14.0
       XXX(1,10)=XXX(1,1)
       YYY(3,10)=YYY(2,1)
       YYY(2,10)=YYY(1,9)
       YYY(1,10)=YYY(1,1)
C
  840  FACTH=(1000.0/PRESS)**0.286
       GO TO I99979
C-----------------------------------------------------------
99977  CONTINUE
C    TO INPUT-SURFACE-ORIENTATION-SPECIFICATIONS
C
C         LINE SFC SLOPE    SFC AZIMUTH  DAY     LATITUDE
C         NO.  DEG-HORIZ=0 DEG S=0       JULIAN  DEG
C
       SLOPE=SLOPE1
       SURFAC=SURFC1
       SLOPE=SLOPE*PI/180.0
       SURFAC=SURFAC*PI/180.
       GO TO I99977
C-----------------------------------------------------------
99975  CONTINUE
C    TO INPUT-HEAT-FLOW-CACULATION-CONTROLS
C
C         LINE NO. OF NO. OF 24 HRS TIME STEP PRINT FREQ
C         NO.  LAYERS REPITIONS     MIN       MIN
C                   1-6    2-5
```

```
C
           TOTTIM=XXX(2,1) - XXX(1,1)
      GO TO I99975
C-----------------------------------------------------------
99973  CONTINUE
C    TO INPUT-INITIAL-TEMPERATURE-PROFILE
C
C         LINE NO. OF
C         NO.  PROFILE POINTS
C
C
C         LINE DEPTH TEMP
C         NO.  CM    DEG C
C
      MAX(5)=NIPTS
      DO 99964 J3=1,NIPTS
      YYY(J3,5)=YYY(J3,5)+273.15
99964  CONTINUE
      GO TO I99973
C-----------------------------------------------------------
99971  CONTINUE
C    TO INPUT-TOP-SURFACE-CONSTANTS
C         LINE EMISSIVITY ABSORBTIVITY MOISTURE
C         NO.                          CONTENT DRY WT.
C
      FACTA=SIGMA*EPSN
C
      GO TO I99971
C-----------------------------------------------------------
99967  CONTINUE
C    TO INPUT-BOTTOM-BOUNDARY-DATA
C
C       IF LFLUXY=0, THERE IS NO HEAT FLUX THROUGH BOTTOM
C       IF IFLUXY LT 0, THERE IS NO AIRSPACE BENEATH BOTTOM
C       IF IFLUXY GT 0, THERE IS AIRSPACE BENEATH BOTTOM
C
      LFLUXY=-1
      IF(.NOT.(LFLUXY.EQ.0)) GO TO 99962
      DPRM0=YYY(NIPTS,5)
      TB=0.
      GO TO 99963
99962  IF(.NOT.(LFLUXY.LT.0)) GO TO 99961
C
      DPRM1=-0.5
      TB=FK(NOMATL)
      BEP=0.0
      BK=0.
      REP=0.
      TR=0.0
      FACTD=0.
      FACTE=0.
      RK=0.
```

```
      DPRM1=DPRM1/697.6
      GO TO 99963
99961  CONTINUE
99963 GO TO I99967
C-----------------------------------------------------------
99969 CONTINUE
C   TO INPUT-LAYER-SPECIFICATIONS
C
C        LINE THICKNESS VERT. GRID THERMAL DIFF HEAT COND
C        NO.  CM        SPACE-CM   CM**2/MIN    CAL/MIN-CM-K
C
      DO 99960 J4=1,NOMATL
      RHOC(J4)=FK(J4)/ALPH(J4)
99960 CONTINUE
C   CONTROL SWITCHES SPECIFIED
C
      NIT=1
      IEFSWT=1
      GO TO I99969
C-----------------------------------------------------------
99799 CONTINUE
C   TO INPUT-VEGETATION-PARAMETERS
C IVEG DETERMINES WHETHER VEGETATION PARAMETERS ARE USED
C OR NOT.  HEIGHT OF THE METEOROLOGICAL INSTRUMENTS FROM
C WHICH THE DAILY DATA ARE TAKEN ARE ASSUMED TO BE 100CM
C ABOVE THE FOLIAGE HEIGHT, SEE TEXT FOR FULLER EXPLANATION.
C
      IF(IVEG.EQ.0) GO TO 1120
      FOLA=1-ALBEDO
      IF(HFOL.GE.ZA)THEN
      ZA=HFOL+100.0
      END IF
      IF(SIGF.LE.0.0)GO TO I99799
      TF=YYY(1,1)
      IVEG=1
      EP1=EPF+EPSN-EPF*EPSN
      Z0=0.131*HFOL**0.997
      CH0=KSQ/(ALOG(ZA/Z0)**2)
      ZDSP=0.701*HFOL**0.979
      CHH=KSQ/(ALOG((ZA-ZDSP)/Z0)**2)
      CHG=(1.-SIGF)*CH0+SIGF*CHH
      DELTMP=1.
      QAF=QSAT(TF)
1120  GO TO I99799
C-----------------------------------------------------------
99988 CONTINUE
C   TO PRINT-INPUT-DATA
C     WRITE(*,139)
      WRITE(*,220)
      WRITE(*,*)' '
      WRITE(*,230)HEADER
      WRITE(*,*)' '
```

```
      WRITE(*,*)' ATMOSPHERIC-SPECIFICATIONS'
      WRITE(*,*)' '
      WRITE(*,*)' ATMOS PRESS  CLOUD TYPE  SHELTER'
      WRITE(*,*)' MB           INDEX       HEIGHT-CM'
      WRITE(*,150)PRESS,NCLOUD,ZA
      WRITE(*,*)' '
      WRITE(*,*)' TIME  AIR TEMP  RH  CLOUD COVER  WIND SPEED'
     &   ,'  SOLAR IRRAD'
      WRITE(*,*)' HRS   DEG C     %  (0-1)         M/S         W/M**2'
      MMAX=2
      WRITE(*,140)(XXX(J,1),YYY(J,1)-273.15,
     &  YYY(J,2)*100.0,YYY(J,3),YYY(J,6)*0.01,YYY(J,4)*697.6,J=1,MMAX)
      WRITE(*,*)' '
      WRITE(*,*)' SURFACE-ORIENTATION-SPECIFICATIONS'
      WRITE(*,*)' '
      WRITE(*,*)' SFC SLOPE    SFC AZIMUTH  DAY     LATITUDE'
      WRITE(*,*)' DEG-HORIZ=0  DEG S=0      JULIAN  DEG'
      WRITE(*,160)SLOPE*180/PI,SURFAC*180.0/PI,DAY,LAT
      WRITE(*,220)
      WRITE(*,*)' HEAT-FLOW-CACULATION-CONTROLS'
      WRITE(*,*)' '
      WRITE(*,*)' NO. OF  NO. OF 24 HRS TIME STEP  PRINT FREQ'
      WRITE(*,*)' LAYERS  REPETITIONS    MIN        MIN'
      WRITE(*,*)' 1-6'
      WRITE(*,180)NOMATL,TOTTIM/24.0,TFRQ,TPRNT
      WRITE(*,*)' '
      WRITE(*,*)' INITIAL-TEMPERATURE-PROFILE'
      WRITE(*,*)' '
      WRITE(*,145)(XXX(J,5),YYY(J,5)-273.15,
     &       J=1,NIPTS)
      WRITE(*,*)' '
      WRITE(*,*)' TOP-SURFACE-CONSTANTS'
      WRITE(*,*)' '
      WRITE(*,*)' EMISS  ALBEDO   '
      WRITE(*,200)EPSN,SMALLA
      WRITE(*,*)' '
      WRITE(*,*)' INPUT-LAYER-SPECIFICATIONS'
      WRITE(*,*)'LAYER  THICKNESS  VERT. GRID  THERMAL DIFF  HEAT COND'
      WRITE(*,*)' NO.    CM         SPACE-CM    CM**2/MIN'
     &   ,'     CAL/MIN-CM-K'
      DO 99956 J4=1,NOMATL
      WRITE(*,210)J4,THK(J4),SFRQ(J4),
     &   ALPH(J4),FK(J4)
99956 CONTINUE
      WRITE(*,*)' '
      WRITE(*,*)' INPUT BOTTOM BOUNDARY DATA'
      WRITE(*,*)' '
      IF(.NOT.(LFLUXY.EQ.0)) GO TO 99958
      WRITE(*,90)LFLUXY
      WRITE(*,92)DPMM0-273.15
      WRITE(*,*)' '
      WRITE(*,*)' '
```

```
      GO TO 99959
99958 IF(.NOT.(LFLUXY.LT.0)) GO TO 99957
      WRITE(*,90)LFLUXY
      WRITE(*,95)DFRM1*697.6
      WRITE(*,*)' '
      GO TO 99959
99957 WRITE(*,90)LFLUXY
      WRITE(*,95)DFRM1*697.6
      WRITE(*,*)'---BOTTOM SURFACE-----  SURFACE BENEATH AIRSPACE TEMP'
      WRITE(*,*)'EMISSIVITY GEOM SHAPE   EMISSIVITY GEOM SHAPE   DEG C'
      WRITE(*,*)'            FACT(0.-1.)             FACT(0.-1.)'
      WRITE(*,97)BEP,BK,REP,RK,TR-273.15
      WRITE(*,*)' '
99959 WRITE(*,*)' '
      IF(IVEG.EQ.0) GO TO I99988
      WRITE(*,*)' VEGETATION PARAMETERS'
      WRITE(*,*)' '
      WRITE(*,*)' COVERAGE    STATE    EMISSIVITY      ALBEDO
     & FOLIAGE HEIGHT'
      WRITE(*,*)' (0.0 -1.0)           (0.0 -1.0)     (0.0-1.0)
     &       (CM)'
      WRITE(*,240)SIGF,STATE,EPF,FOLA,HFOL
      WRITE(*,*)' '
      WRITE(*,*)' '
      WRITE(*,*)' '
      GO TO I99988
C------------------------------------------------------------
99985 CONTINUE
C    TO CALCULATE-INSOLATION-ON-SLOPE-SURFACE
C
C
C      SOLVE-SOLAR-ZENITH
      ASSIGN 99951 TO I99952
      GO TO 99952
C
C      SOLVE-SOLAR-AZIMUTH
99951 ASSIGN 99949 TO I99950
      GO TO 99950
C
C      CALCULATE-SLOPE-ATMOS-ATTEN-AND-CLOUD-ADJUSTMENTS
99949 ASSIGN 99947 TO I99948
      GO TO 99948
C
99947 CONTINUE
C
99953 GO TO I99985
C------------------------------------------------------------
99955 CONTINUE
C    TO ZERO-VARIABLES
C
      I=0
      GO TO I99955
```

```
C-----------------------------------------------------------
99952  CONTINUE
C    TO SOLVE-SOLAR-ZENITH
C
       TYME=AMOD(TIME,24.0)
       T0=2.0*PI*(DAY-1.0)/365.0
       DECL=0.006918-0.399912*COS(T0)+0.070257*SIN(T0)
     &      -0.006758*COS(2.0*T0)+0.000907*SIN(2.0*T0)
     &      -0.002697*COS(3.0*T0)+0.001480*SIN(3.0*T0)
       ELF=(LAT/180*PI)
       TIMER=(TYME/12*PI)+PI
       IF(TIMER.GT.2.*PI)TIMER=TIMER-2.*PI
       AA=COS(DECL)*COS(ELF)*COS(TIMER)
       BB=SIN(DECL)*SIN(ELF)
       C=AA+BB
       Z=ACOS(C)
       GO TO I99952
C-----------------------------------------------------------
99950  CONTINUE
C    TO SOLVE-SOLAR-AZIMUTH
C
       XNUM=-COS(DECL)*SIN(TIMER)
       XDNOM=COS(ELF)*SIN(DECL)-SIN(ELF)*COS(TIMER)
       SAZ=ATAN(XNUM/XDNOM)
       IF(.NOT.(XNUM.LT.0.0.AND.XDNOM.GT.0.0)) GO TO 99944
       SAZ=SAZ+PI
       GO TO 99945
99944  IF(.NOT.(XNUM.GT.0.0.AND.XDNOM.GT.0.0)) GO TO 99943
       SAZ=SAZ-PI
99943  CONTINUE
99945  GO TO I99950
C-----------------------------------------------------------
99948  CONTINUE
C    TO CALCULATE-SLOPE-ATMOS-ATTEM-AND-CLOUD-ADJUSTMENTS
C
       SICF=COS(Z)*COS(SLOPE)+SIN(Z)*SIN(SLOPE)
     &  *COS(SAZ-SURFAC)
       IF(.NOT.(SICF.LT.0.0.OR.COS(Z).LE.0.0)) GO TO 99941
       SUN=0.0
       GO TO 99942
99941  M=1/COS(Z)
       IF(.NOT.(M.GE.0.0)) GO TO 99939
       TAL=0.02023
       IF(DAY.GE.92.0 .AND. DAY.LE.152.0)TAL=-0.02290
       TD=5352.2/(21.4-ALOG(RH*ESAT(TA)))
       WATER=EXP(0.07074*(TD-273.15)+TAL)
       AB=0.271*(WATER*M)**0.303
       A0=0.085-0.247*ALOG10(PRESS/1000.*1./M)
       ARG1=((1.-AB)*0.349+(1.-A0)/(1.-A0*0.2)*0.651)
       GO TO 99940
99939  ARG1=1.0
99940  QP=2.0*ARG1
```

```
      QO=QP*SICF
      IF(.NOT.(NCLOUD.EQ.0)) GO TO 99937
      SUN=QO
      GO TO 99938
99937 CONTINUE
      ARG2=-(BCL(NCLOUD)-.059)*M
      CTF=(ACL(NCLOUD)/94.4)*EXP(ARG2)
      SUN=QO-((CLOUD*CLOUD)*(QO-QO*CTF))
99938 CONTINUE
99942 CONTINUE
      GO TO I99948
C-----------------------------------------------------------
99983 CONTINUE
C     TO CALCULATE-TABLE-SLOPE-AND-INTERCEPT
      I=1
      GO TO 99935
99936 IF(I.GT.10) GO TO 99934
99935 IMAX=MAX(I)
      IF(IMAX.EQ.0)GO TO 99931
      J=1
      GO TO 99932
99933 IF(J.EQ.IMAX) GO TO 99931
99932 FMM(J,I)=(YYY(J+1,I)-YYY(J,I))/(XXX(J+1,I)-XXX(J,I))
      BBB(J,I)=YYY(J,I)-FMM(J,I)*XXX(J,I)
      J=J+1
      GO TO 99933
99931 I=I+1
      GO TO 99936
99934 GO TO I99983
C-----------------------------------------------------------
99930 CONTINUE
C     TO GET-TABLE-VALUES
C
      IMAX=MAX(NTABL)
      IJ=1
      IF(.NOT.(XN.GE.XXX(IMAX,NTABL))) GO TO 99928
      YN=YYY(IMAX,NTABL)
      GO TO 99929
99928 IF(IJ.EQ.IMAX+1) GO TO 99927
      JJ=IJ
      IF(.NOT.(XXX(IJ,NTABL).LT.XN)) GO TO 99925
      IJ=IJ+1
      GO TO 99928
99925 IF(.NOT.(XXX(IJ,NTABL).EQ.XN)) GO TO 99924
      YN=YYY(JJ,NTABL)
      IJ=IMAX+1
      GO TO 99928
99924 IF(.NOT.(XXX(IJ,NTABL).GT.XN)) GO TO 99923
      JJ=JJ-1
      YN=FMM(JJ,NTABL)*XN+BBB(JJ,NTABL)
      IJ=IMAX+1
99923 CONTINUE
```

```
      GO TO 99928
99927 CONTINUE
99929 GO TO I99930
C-------------------------- ----------------------------------
99981 CONTINUE
C    TO CALCULATE-SURFACE-AND-LAYER-TEMPERATURE
C
C      SET-UP-INITIAL-CONDITIONS
       ASSIGN 99921 TO I99922
       GO TO 99922
C
C      PRINT-OUTPUT-HEADING
99921  ASSIGN 99919 TO I99920
       GO TO 99920
C
99919  CONTINUE
C
C      RUN-HEAT-FLOW-PROGRAM
       ASSIGN 99917 TO I99918
       GO TO 99918
C
C      SET-UP-AND-PRINT-OUTPUT
99917  ASSIGN 99915 TO I99916
       GO TO 99916
C
99915  IF(IRETRN.EQ.1) GO TO 4100
       GO TO 99919
 4100  CONTINUE
       GO TO I99981
C------------------------------------------------------------
99922  CONTINUE
C    TO SET-UP-INITIAL-CONDITIONS
C
       PTYME=TOTTIM-24.0
       TIME=XXX(1,1)
       DIST=0.
       IFLAG=0
       IF (TFRQ.LE.0) TFRQ=TOTTIM
       DELT=TFRQ/60.
       ITIME=MAX1(TOTTIM/DELT+.9,1.1)
       IX=1
       IY=1
       GO TO 99913
99914  IF(IX.GT.NOMATL) GO TO 99912
99913  INTR(IX)=IY
       IF (SFRQ(IX).LE.0.) SFRQ(IX)=THK(IX)/10.
       NX(IX)=MAX1(THK(IX)/SFRQ(IX)+.9,1.1)
       RR(IX)=60.0*DELT/(SFRQ(IX)*SFRQ(IX))
C
C CALCULATION OF NUMERICAL STABILITY PARAMETER, TO
C ENSURE NUMERICAL STABILITY.
C
```

```
      STABN(IX)=ALPH(IX)*RR(IX)
      IF(STABN(IX).GT.0.5)THEN
      STABN(IX)=0.5
      END IF
C
      LAYERS=0
      GO TO 99910
99911 IF(LAYERS.GT.NX(IX)) GO TO 99909
99910 XN=DIST
      NTABL=5
      DEPTH(IY)=XN
C
C     GET-TABLE-VALUES
      ASSIGN 99908 TO I99930
      GO TO 99930
C
99908 TEMP=YN
      STOR(1,IY)=TEMP
      STOR(5,IY)=TEMP
      STOR(6,IY)=FK(IX)
      STOR(7,IY)=RHOC(IX)
      STOR(4,IY)=0.
      STOR(2,IY)=FK(IX)
      STOR(3,IY)=RHOC(IX)
      IY=IY+1
      DIST=DIST+SFRQ(IX)
      LAYERS=LAYERS+1
      GO TO 99911
99909 IX=IX+1
      DIST=DIST-SFRQ(IX-1)
      GO TO 99914
99912 JMAX=IY-1
      INTR(IX)=JMAX
      NPRNT=MAX1(TPRNT/TFRQ+.9,1.1)
      IPRNT=NPRNT
      GO TO I99922
C-------------------------------------------------------------
99920 CONTINUE
C    TO PRINT-OUTPUT-HEADING
C
C     IF(OUTCD.EQ.1)GO TO 1610
C     IF(IVEG.GT.0)  GO TO 1420
C     WRITE(*,350)
C     WRITE(*,360)
C     WRITE(*,370)
C     WRITE(*,380)
C     GO TO I99920
C1420 WRITE(*,310)
C     WRITE(*,320)
C     WRITE(*,330)
C     WRITE(*,340)
C     GO TO I99920
```

```
C1610  WRITE(*,390)
       GO TO I99920
C-----------------------------------------------------------
99918  CONTINUE
C     TO RUN-HEAT-FLOW-PROGRAM
C
       IF(.NOT.(IFLAG2.EQ.0)) GO TO 99907
       ITER=NIT
       TIME=TIME+DELT
99907  ZZA=STOR(5,1)
       ZZB=STOR(5,JMAX)
       TEML=ZZA
       TEMR=ZZB
C
C
C      CALCULATE-BOUNDARY-CONDITIONS
C CALCULATE ENERGY-BUDGET TERMS WITH VEGETATION OR WITHOUT
C
       IF(IVEG.EQ.0)GO TO 930
       ASSIGN 99905 TO I99800
       GO TO 99800
 930   ASSIGN 99905 TO I99906
       GO TO 99906
C
C      CALCULATE-UPPER-BOUNDARY-VALUES
C USING ENERGY-BUDGET, FIND TOP TEMPERATURE WITH VEGETATION
C OR WITHOUT.
C
99905  IF(IVEG.EQ.0) GO TO 900
       ASSIGN 99903 TO I99797
       GO TO 99797
 900   ASSIGN 99903 TO I99904
       GO TO 99904
C
99903  IX=1
       J=2
       IMATL=NOMATL
       IF(.NOT.(NOMATL.EQ.1)) GO TO 99901
       IZ=NX(IX)-1
       IF(.NOT.(IZ.GT.0)) GO TO 99900
C
C      CALCULATE-INSIDE-MATERIAL-VALUES
       ASSIGN 99898 TO I99899
       GO TO 99899
C
99898  CONTINUE
99900  GO TO 99902
99901  GO TO 99896
99897  IF(IMATL.LT.1) GO TO 99895
99896  IF(.NOT.(IMATL.GT.1)) GO TO 99893
       IZ=NX(IX)-1
       IF(.NOT.(IZ.GT.0)) GO TO 99892
```

```
C
C      CALCULATE-INSIDE MATERIAL-VALUES
       ASSIGN 99891 TO I99899
       GO TO 99899
C
99891  CONTINUE
C
C      CALCULATE-INTERFACE-VALUES
99892  ASSIGN 99889 TO I99890
       GO TO 99890
99889  GO TO 99894
99893  IZ=NX(IX)-1
       IF(.NOT.(IZ.GT.0)) GO TO 99888
C
C      CALCULATE-INSIDE-MATERIAL-VALUES
       ASSIGN 99887 TO I99899
C
       GO TO 99899
99887  CONTINUE
99888  CONTINUE
99894  IMATL=IMATL-1
       GO TO 99897
99895  CONTINUE
C
C      CALCULATE-LOWER-BOUNDARY-VALUES
99902  ASSIGN 99883 TO I99886
       GO TO 99886
C
99883  GO TO I99918
C-------------------------------------------------------------
99906  CONTINUE
C    TO CALCULATE-BOUNDARY-CONDITIONS
       B = -FK(1)
       T=TIME
C
C      CALCULATE-BOTTOM-BOUNDARY-HEAT-TERMS-APRM-DPRM-BPRM
       ASSIGN 99880 TO I99881
       GO TO 99881
C
C
C      ATMOSPHERIC-INFRARED-EMISSION-ATERM
99880  ASSIGN 99878 TO I99879
       GO TO 99879
C
99878  CONTINUE
C   CALCULATE-SOLAR-INSOLATION-FOR-DAY-AND-TIME
       DAY=XXX(1,8)
       ASSIGN 42 TO I99985
       GO TO 99985
 42    BTERM=SUN
       IF(BTERM.GT.0)BTERM=BTERM*SMALLA
C
```

```
C       CALCULATE-CONVECTION-BTERM
        ASSIGN 99876 TO I99877
        GO TO 99877
C
C
C       CALCULATE-EVAPORATIVE-HEAT-LOSS-DTERM
99876   ASSIGN 99874 TO I99875
        GO TO 99875
C
99874   D = ATERM + BTERM - HTERM-DTERM
  521   CONTINUE
        GO TO I99906
C-----------------------------------------------------------
99881 CONTINUE
C     TO CALCULATE-BOTTOM-BOUNDARY-HEAT-TERMS-APRM-DPRM-BPRM
C
        BPRM=TB
        IF(.NOT.(TB.EQ.0.0)) GO TO 99872
        APRM=1.0
        DPRM=DPRM0
        GO TO 99873
99872   APRM=FACTE*TEMR*TEMR*TEMR
        DPRM=DPRM1
99873   GO TO I99881
C-----------------------------------------------------------
99879   CONTINUE
C     TO ATMOSPHERIC-INFRARED-EMISSION-ATERM
        XN=TIME
        NTABL=2
C
C       GET-TABLE-VALUES
        ASSIGN 99867 TO I99930
        GO TO 99930
C
99867   RH=YN
        XN=TIME
        NTABL=10
C
C       GET-TABLE-VALUES
        ASSIGN 99866 TO I99930
        GO TO 99930
C
99866   TA=YN
        XN=TIME
        NTABL=3
C
C       GET-TABLE-VALUES
        ASSIGN 99865 TO I99930
        GO TO 99930
C
99865   CLOUD=YN
        TAK=TA
```

```
      TAC=(TAK-273.15)
      EA=6.108*RH*EXP((AC*TAC)/(TAK-BC))
      ALPHI=(0.61+0.05*SQRT(EA))*(1.0+(CLR(NCLOUD)*(CLOUD**2)))
      DOWNIR=0.8132E-10*TAK**4*ALPHI
      ATERM=DOWNIR
      GO TO I99879
C------------------------------------------------------------
99877 CONTINUE
C    TO CALCULATE-CONVECTION-HTERM
C
      XN=TIME
      NTABL=6
C
C     GET-TABLE-VALUES
      ASSIGN 99862 TO I99930
      GO TO 99930
C
99862 SPEED=YN
      TAK=TA
      ZASH=ZA
      TSK=TEML
      RHOA=-0.001*0.348*PRESS/TAK
 1200 THETAZ=TAK*FACTH
      THETAS=TSK*FACTH
      DTHETA=(THETAZ-THETAS)/ZASH
      DU=SPEED/ZASH
      THETAV=(THETAZ+THETAS)/2.0
      RI=G*DTHETA/(THETAV*DU**2)
      COE1=15.0
      COE2=1.175
      EX=.75
      IF(TSK.GT.TAK)GO TO 31
      IF(RI.GT.0.2)RI=.19999
      COE1=5.0
      COE2=1.0
      EX=2.0
   31 HTER=RHOA*KSQ*ZASH**2*DU
     & *(COE2*(1.0-COE1*RI)**EX)
      HTERM=HTER*CP*DTHETA
99864 GO TO I99877
C------------------------------------------------------------
99875 CONTINUE
C    TO CALCULATE-EVAPORATIVE-HEAT-LOSS-DTERM
C
      XN=TIME
      NTABL=2
C
C     GET-TABLE-VALUES
      ASSIGN 99859 TO I99930
      GO TO 99930
C
99859 RH=YN
```

```
      XN=TIME
      NTABL=10
C
C     GET-TABLE-VALUES
      ASSIGN 99858 TO I99930
      GO TO 99930
C
99858 CTEMA=YN
      KTEMPA=CTEMA
      CTEMA=CTEMA-273.15
      KTEMPG=TEML
      ES=EXP((AC*(KTEMPG-273.15))/(KTEMPG-BC))*6.1071
      EA=EXP((AC*CTEMA)/(KTEMPA-BC))*6.1071*RH
      DG=0.622/PRESS*(EA-ES)*WET/ZA
      XL=597.3-0.566*(CTEMA+KTEMPG-273.15)/2.0
      DTERM=HTER*XL*DG
      GO TO 99861
99860 DTERM=0.0
99861 GO TO I99875
C-----------------------------------------------------------
99904 CONTINUE
C    TO CALCULATE-UPPER-BOUNDARY-VALUES
      T1=STABN(1)*(STOR(1,3)-2.*STOR(1,2)+STOR(1,1))+STOR(1,2)
      III=0
  830 III=III+1
      T2=STOR(5,1)**4*FACTA*SFRQ(1)+FK(1)*STOR(5,1)
     &  -(FK(1)*T1+D*SFRQ(1))
      T2=T2/(4.*FACTA*SFRQ(1)*STOR(5,1)**3+FK(1)-SFRQ(1)*DDDT)
      STOR(5,1)=STOR(5,1)-T2
      TEML=STOR(5,1)
C
C SURFACE    ATURE (TEML, STOR(5,1)) NOT ALLOWED TO RISE
C ABOVE 0      ST SNOW PRESENT.  THE SNOWPACK IS SATURATED
C AT 0°C AND UNSATURATED AT TEMPERATURES BELOW 0°C.
C
      IF(TEML.GE.273.15)THEN
      TEML=273.15
      WET=1.0
      ELSE
      WET=0.0
      END IF
      IF(STOR(5,1).GT.273.15)THEN
      STOR(5,1)=273.15
      END IF
C
      GTERM=-FK(1)*(STOR(5,1)-T1)/SFRQ(1)
      ASSIGN 825 TO I99877
      GO TO 99877
  825 ASSIGN 810 TO I99875
      GO TO 99875
  810 DNEW=ATERM+BTERM-HTERM-DTERM
      IF(ABS(T2).LT.0.005 .OR. III.GT.30)GO TO I99904
```

```
      DDDT=-(DNEW-D)/T2
      D=DNEW
      GO TO 830
C
C------------------------------------------------------------
99899 CONTINUE
C    TO CALCULATE-INSIDE-MATERIAL-VALUES
C
      GO TO 99856
99857 IF(IZ.LE.0) GO TO 99855
99856 CONTINUE
      STOR(5,J)=STOR(1,J)+STABN(IX)*(STOR(1,J-1)-2.*STOR(1,J)
     & +STOR(1,J+1))
      J=J+1
      IZ=IZ-1
      GO TO 99857
99855 GO TO I99899
C------------------------------------------------------------
C    TO CALCULATE-INTERFACE-VALUES
C
99890 CONTINUE
      BCOEF=STOR(6,J-1)/SFRQ(IX)
      DCOEF=STOR(6,J+1)/SFRQ(IX+1)
      CCOEF=BCOEF+DCOEF
      ACOEF=BCOEF/(2.*STABN(IX))+DCOEF/(2.*STABN(IX+1))
      STOR(5,J)=STOR(1,J)+(BCOEF*STOR(1,J-1)-CCOEF*STOR(1,J)+DCOEF*
     & STOR(1,J+2))/ACOEF
      STOR(5,J+1)=STOR(5,J)
      IX=IX+1
      J=J+2
      GO TO I99890
C------------------------------------------------------------
C    TO CALCULATE-LOWER-BOUNDARY-VALUES
99886 IF(LFLUXY.EQ.0) GO TO 880
      I=1
      R2=FACTD
  870 CONTINUE
      R1=SIGMA*BEP*BK*STOR(5,J)**4
      G1=-FK(NOMATL)*(STOR(5,J)-STOR(1,J-1))/SFRQ(NOMATL)
      F2=4.0*SIGMA*BEP*BK*STOR(5,J)**3-FK(NOMATL)/SFRQ(NOMATL)
      F2= - (R2-R1+G1+DPRM)/F2
      STOR(5,J)=STOR(5,J) + F2
      I=I+1
      IF(ABS(F2).GT.0.01 .AND. I.LE.30) GO TO 870
  880 IF(LFLUXY.EQ.0) STOR(5,J)=STOR(5,J)
      GO TO I99886
C------------------------------------------------------------
99916 CONTINUE
C    TO SET-UP-AND-MANIPULATE OUTPUT
C
      IFLAG2=0
      IRETRN=0
```

```
      IF(ITER.LE.1) GO TO 1245
      ITER=ITER-1
      IF (IEFSWT.NE.0) GO TO 1328
      IF (IPRNT.LE.1) GO TO 1244
      IF (ITIME.GT.1) GO TO 1328
 1244 CONTINUE
C
C     MANIPULATE OUTPUT
      ASSIGN 99846 TO I99847
      GO TO 99847
C
99846 GO TO 1328
 1245 IF (ITIME.GT.1) GO TO 1269
C
C     MANIPULATE OUPUT
      ASSIGN 99845 TO I99847
      GO TO 99847
C
99845 IRETRN=1
      GO TO 1335
 1269 ITIME=ITIME-1
      IF (IPRNT.LE.1) GO TO 1279
      IPRNT=IPRNT-1
      GO TO 1303
 1279 CONTINUE
C
C     MANIPULATE OUTPUT
      ASSIGN 99844 TO I99847
      GO TO 99847
C
99844 IPRNT=NPRNT
 1303 J=1
      IZ=NOMATL
 1306 IX=NX(IZ)+1
 1311 STOR(1,J)=STOR(5,J)
      STOR(2,J)=STOR(6,J)
      STOR(3,J)=STOR(7,J)
      J=J+1
      IF (IX.LE.1) GO TO 1329
      IX=IX-1
      GO TO 1311
 1329 IF(IZ.LE.1) GO TO 1335
      IZ = IZ-1
      GO TO 1306
 1328 IFLAG2=1
 1335 CONTINUE
      GO TO I99916
C-----------------------------------------------------------
99847  CONTINUE
C OUTPUT MANIPULATION
C HOURLY ENERGY VALUES FOR BOTH UNVEGETATED AND UNVEGETATED SURFACES
C ARE CONVERTED INTO lyhr^-1.  THE ENERGY VALUES, SURFACE AND BASAL
```

```
C TEMPERATURES AND CORRESPONDING HOUR OF THE DAY ARE PLACED IN A DATA
C MATRIX, DATMX.
C
        TFACX=1.0
        IF(.NOT.(TIME.GT.PTYME)) GO TO 99843
        DO 99842 JKX=1,NOMATL+1
        IJ=INTR(JKX)
        TITLE(JKX)=(STOR(5,IJ)-273.15)
99842   CONTINUE
        NDX=TIME
        IF(NDX.EQ.0)NDX=1
C
C RESULTS CALCULATED IN calcm^-2min^-1 IE. lymin^-1 AND
C CONVERTED TO lyhr^-1 BY *60.  THE DAILY TOTAL IS THEN DIVIDED
C BY 24 (ELSEWHERE IN THE PROGRAM) TO HAVE ANSWER IN MJm^-2day^-1.
C MJm^-2day^-1. IS NOW THE MORE WIDELY USED UNIT AND THEREFORE IS
C USED.
C
        STP=TITLE(1)
        BOTTP=STOR(5,J)-273.15
        K10=K10+1
        IF(IVEG.EQ.1) GO TO 1110
C
C ENERGY VALUES FOR UNVEGETATED SURFACE, CONVERTED TO lyhr^-1.
C
        IGBR=(0.813E-10*EPSN*STOR(5,1)**4)*60
        ISOL=(BTERM/SMALLA)*60
        IABSOR=(ISOL*SMALLA)
        IATERM=ATERM*60
        IHTERM=HTERM*60
        IDTERM=DTERM*60
C
1110    CONTINUE
        DATMX(K10,1)=TIME
        DATMX(K10,2)=TITLE(1)
C
C CALCULATE VEGETATION RADIANCE VALUES IF VEGETATION MODELLED
C
        ASSIGN 1400 TO I1410
        IF(IVEG.EQ.1) GO TO 1410
1400    CONTINUE
C
        IF(IVEG.EQ.0)THEN
C*************************************************************************
C OPTION 2-HOURLY VALUES FOR ENERGY-BUDGET VALUES.
C INSERT:
        WRITE(9,190)AMOD(TIME,24.),TITLE(1),IBGR,ISOL,IABSOR,
     &  IATERM,IHTERM,IDTERM
C*************************************************************************
C
        DATMX(K10,3)=IGBR
        DATMX(K10,4)=ISOL
```

```
        DATMX(K10,5)=IABSOR
        DATMX(K10,6)=IATERM
        DATMX(K10,7)=IHTERM
        DATMX(K10,8)=IDTERM
        DATMX(K10,9)=BOTTP
     ELSE
C************************************************************************
C OPTION 2-HOURLY VALUES FOR ENERGY-BUDGET VALUES.
C INSERT:
        WRITE(9,270)AMOD(TIME,24.),ISURFG+IREFRA,ISURFG,
     &  TEFFR-273.15,TEFF-273.15,TEML-273.15,TF-273.15,ISOL,SG
C************************************************************************
C
        DATMX(K10,3)=GRNDGB*60
        DATMX(K10,4)=SG
        DATMX(K10,5)=IABSOR
        DATMX(K10,6)=RLD*60
        DATMX(K10,7)=HSG*60
        DATMX(K10,8)=ELG*XL1*60
        DATMX(K10,9)=BOTTP
        END IF
99843   GO TO I99847
C---------------------------------------------------------------
99800  CONTINUE
C      TO CALCULATE-BOUNDARY-CONDITIONS-WITH-VEG
         T=TIME
         XN=TIME
         NTABL=6
C
C        GET-TABLE-VALUES
         ASSIGN 960 TO I99930
         GO TO 99930
C
 960     UA=YN
         XN=TIME
         NTABL=4
C
C        ATMOSPHERIC-INFRARED-EMISSION-ATERM
         ASSIGN 980 TO I99879
         GO TO 99879
C
C    CALCULATE INCOMING SOLAR RADIATION.
 980     CONTINUE
         DAY=XXX(1,8)
         ASSIGN 43 TO I99985
         GO TO 99985
 43      SOL=SUN
C
         IF(UA.LT.10.0)UA=10.0
         UAF=0.83*SIGF*UA*SQRT(CHH)+(1.-SIGF)*UA
         DELTMP=5.
         CF=0.01*(1.+30.0/UAF)
```

```
      DU=(UA-UAF)/ZA
      RS=1/(.05+.0021*(SOL*60))
      RC=RS*STATE/(7.0*SIGF)
      ATF(1)=TF
      ASSIGN 1210 TO I950
      GO TO 950
1210  CONTINUE
      FEB(1)=FENB
      NDEX=0
1240  TF=TF+DELTMP
      NDEX=NDEX+1
      ASSIGN 1220 TO I950
      GO TO 950
1220  CONTINUE
      IF(NDEX.EQ.3.AND.FENB.LT.0.0)THEN
      FENB=FENB*(-1.0)
      END IF
      FEB(2)=FENB
      IF(FEB(1)*FEB(2).LT.0.0) GO TO 1230
      IF(NDEX.EQ.5)THEN
      GOTO 1230
      END IF
      IF(ABS(FEB(2)).GT.ABS(FEB(1)))DELTMP=-5.
      IF(NDEX.LT.100)GO TO 1240
      WRITE(*,*)'FOLIAGE ENERGY BUDGET HAS NOT CROSSED X-AXIS'
      WRITE(*,*)'AFTER 100 SEARCH STEPS. CHECK INPUT DATA.'
      STOP
1230  CONTINUE
      NDEX1=0
      ATF(2)=TF
1270  SLOPE2=(FEB(2)-FEB(1))/(ATF(2)-ATF(1))
      BINT=FEB(1)-SLOPE2*ATF(1)
      TF0=-BINT/SLOPE2
      NDEX1=NDEX1+1
      IF(ABS(TF-TF0).LE.0.01)GO TO 1260
      IF(NDEX1.EQ.5)THEN
      GOTO 1260
      END IF
      TF=TF0
      ASSIGN 1250 TO I950
      GO TO 950
1250  CONTINUE
      IF(FENB*FEB(2).GT.0.0)IP=2
      IF(FENB*FEB(1).GT.0.0)IP=1
      ATF(IP)=TF
      FEB(IP)=FENB
      GO TO 1270
1260  GO TO I99800
C-------------------------------------------------------------
C     TO CALCULATE-UPPER-BOUNDARY-VALUES-FOR-FOLIAGE
99797 CONTINUE
      DELTMP=5.
```

```
        ATF(1)=TEML
        ASSIGN 1310 TO I1300
        GO TO 1300
1310    CONTINUE
        FEB(1)=FENB
        NDEX=0
1340    TEML=TEML+DELTMP
        NDEX=NDEX+1
        ASSIGN 1320 TO I1300
        GO TO 1300
1320    CONTINUE
        FEB(2)=FENB
        IF(FEB(1)*FEB(2).LT.0.0) GO TO 1330
        IF(NDEX.EQ.5)THEN
        GOTO 1330
        END IF
        IF(ABS(FEB(2)).GT.ABS(FEB(1)))DELTMP=-5.
        IF(NDEX.LT.100)GO TO 1340
        WRITE(*,*)'GROUND ENERGY BUDGET HAS NOT CROSSED X-AXIS'
        WRITE(*,*)'AFTER 100 SEARCH STEPS. CHECK INPUT DATA.'
        STOP
1330    CONTINUE
        NDEX1=0
        ATF(2)=TEML
1370    SLOPE2=(FEB(2)-FEB(1))/(ATF(2)-ATF(1))
        BINT=FEB(1)-SLOPE2*ATF(1)
        TF0=-BINT/SLOPE2
        NDEX1=NDEX1+1
        IF(ABS(TEML-TF0).LE.0.001)GO TO 1360
        IF(NDEX1.EQ.5)THEN
        GOTO 1360
        END IF
        TEML=TF0
        ASSIGN 1350 TO I1300
        GO TO 1300
1350    CONTINUE
        IF(FENB*FEB(2).GT.0.0)IP=2
        IF(FENB*FEB(1).GT.0.0)IP=1
        ATF(IP)=TEML
        FEB(IP)=FENB
        GO TO 1370
1360    STOR(5,1)=TEML
        IF(TEML.GE.273.15)THEN
        TEML=273.15
        END IF
        GO TO I99797
C-------------------------------------------------------------
C     TO CALCULATE-ENERGY-BUDGET
 950    TAF=(1.-SIGF)*TA+SIGF*(0.3*TA+0.6*TF+0.1*TEML)
        DTHETA=(TA-TF)*FACTH/ZA
        THETAV=(TA+TF)*FACTH/2.0
        RI=G*DTHETA/(THETAV*DU**2)
```

```
      RHOAF=-0.001*.348*PRESS/((TF+TA)/2.)
      COE1=15.
      COE2=1.175
      EX=.75
      IF(RI.LE.0.)GO TO 1280
      IF(RI.GT.0.2)RI=0.199
      COE1=5
      COE2=1.
      EX=2.0
1280  CONTINUE
      HTER=RHOAF*KSQ*ZA**2*DU
     & *COE2*(1.-COE1*RI)**EX
      HSF=HTER*CP*DTHETA*60.
      XL=597.3-0.566*TAF
      RA=(ALOG((ZA-ZDSP)/Z0)*COE2*((1.-COE1*RI)**EX))**2
     & /(.16*UA)
      RDP=RA/(RS+RA)
      QF=RDP*QSAT(TF)+(1.-RDP)*QAF
      QAF=(1.-SIGF)*Q(TA)+SIGF*(Q(TA)*0.3+QF*0.6+QG*0.1)
      EF=-(RHOAF*CP/0.66)*(ESAT(TF)-E(TA))/(RA+RC)*60.
      IF(EF.LT.0.0)EF=0.0
      SHRW=FOLA*SOL
      XLNGW=EPF*ATERM
      TG4=EPF*EPSN/EP1*SIGMA*TEML**4
      TF4=(EP1+EPSN)/EP1*EPF*SIGMA*TF**4
      FENB=SIGF*(SHRW+XLNGW+TG4-TF4)-HSF-EF
      GO TO I950
C-----------------------------------------------------------
C     TO CALCULATE-ENERGY-BUDGET-FOR-GROUND
 1300 CONTINUE
      T1=ALPH(1)*RR(1)*(STOR(1,3)-2.*STOR(1,2)+STOR(1,1))
     & +STOR(1,2)
      TF4=SIGMA*TF**4
      TG4=SIGMA*TEML**4
      QG=WET*QSAT(TEML)+(1.-WET)*QAF
      RHOAG=0.001*0.348*PRESS/TAF
      XL1=597.3-0.566*(TAF+TEML-2.0*273.15)/2.
      SG=(1.-SIGF)*SOL
      RLU=(1.-SIGF)*(EPSN*TG4+(1.-EPSN)*ATERM)
     & +SIGF*(EPSN*TG4+(1.-EPSN)*EPF*TF4)/EP1
      RLD=(1.-SIGF)*ATERM+SIGF*(EPF*TF4+(1.-EPF)*EPSN*TG4)/EP1
      HSG=RHOAG*CP*CHG*UAF*(TEML-TAF)*60.
      ELG=RHOAG*CHG*UAF*(QG-QAF)*60.
      FENB=SMALLA*SG-RLU+RLD-HSG-ELG*XL1+(T1-TEML)/SFRQ(1)*FK(1)
      GO TO I1300
C-------------------------------------------------------------
C     TO CALCULATE-RADIANCE-VALUES
 1410 CONTINUE
      REFRAD=((1.-SIGF)*(1-EPSN)+SIGF*(1-EPF))*DOWNIR
      FOLGB=EPF*0.8132E-10*TF**4
      GRNDGB=EPSN*0.8132E-10*TEML**4
      SURFGB=SIGF*FOLGB+(1.-SIGF)*GRNDGB
```

```
      EEF=SIGF*EPF+(1.-SIGF)*EPSN
      TEFF=(SURFGB/0.8132E-10)**.25
      ISURFG=SURFGB*60
      TEFFR=(((SURFGB+REFRAD)/(0.8132E-10))**.25)
      IREFRA=REFRAD*60
      ISOL=SOL*60
      SG=((1.0-SIGF)*SOL)*60
      IABSOR=SMALLA*SG
      GO TO I1410
C -------------------------------------------------------------
      END
```

```
C************************************************************************
C OPTION 3-MASS CONSERVATION ROUTINE
C
C FOR A 2-LAYER PACK
3001    DELRNS=(DELQM/(LHEATF*VNEWSN(1,6)*1000)))*100
        IF(DELRNS.GT.0.0)THEN
          IF(DELRNS.GE.THKMX2(1,1))THEN
          ABC=DELRNS-THKMX2(1,1)
          DFG=THKMX2(1,1)
          THKMX2(1,1)=0.0
          DELQM=(ABC*LHEATF*(VNEWSN(1,6)*1000)))/100
          DELROS=(DELQM/(LHEATF*(VOLDSN(1,6)*1000)))*100
            IF(DELROS.GE.THKMX2(2,1))THEN
            GOTO 5002
            ELSE
            THKMX2(2,1)=THKMX2(2,1)-DELROS
            DEPTH=THKMX2(2,1)
            NOMATL=1
            NIPTS=2
            DO 800 J=1,6
             THKMX1(   J)=VOLDSN(1,J)
800         CONTINUE
            THKMX1(1,1)=DEPTH
            DEPMX1(1,2)=AVSTP
            DEPMX1(2,2)=AVBOTTP
            DEPMX1(2,1)=DEPTH
            GOTO 5000
            END IF
          ELSE
          THKMX2(1,1)=THKMX2(1,1)-DELRNS
          DEPMX2(1,2)=AVSTP
          DEPMX2(3,2)=AVBOTTP
          DEPMX2(3,1)=DEPTH
          DEPMX2(2,1)=THKMX2(1,1)
          DEPMX2(2,2)=((DEPMX2(2,1)/DEPTH)*(AVBOTTP-AVSTP))+AVSTP
          GOTO 5000
          END IF
        ELSE
        GOTO 5000
        END IF
C
C FOR A 1-LAYER PACK
4000    IF(THKMX1(1,6).EQ.VNEWSN(1,6))THEN
        DELRNS=(DELQM/(LHEATF*(VNEWSN(1,6)*1000)))*100
          IF(DELRNS.GT.0.0)THEN
            IF(DELRNS.GE.THKMX1(1,1))THEN
            GOTO 5002
            ELSE
            THKMX1(1,1)=THKMX1(1,1)-DELRNS
            DEPTH=THKMX1(1,1)
            DEPMX1(1,2)=AVSTP
            DEPMX1(2,2)=AVBOTTP
```

```
          DEPMX1(2,1)=THKMX1(1,1)
          GOTO 5000
          END IF
        ELSE
        GOTO 5000
        END IF
      ELSE
      DELROS=(DELQM/(LHEATF*(VOLDSN(1,6)*1000)))*100
        IF(DELROS.GT.0.0)THEN
          IF(DELROS.GE.THKMX1(1,1))THEN
          GOTO 5002
          ELSE
          THKMX1(1,1)=THKMX1(1,1)-DELROS
          DEPTH=THKMX1(1,1)
          DEPMX1(1,2)=AVSTP
          DEPMX1(2,2)=AVBOTTP
          DEPMX1(2,1)=THKMX1(1,1)
          GOTO 5000
          END IF
        ELSE
        GOTO 5000
        END IF
      END IF
C
5000  IF(NOMATL.EQ.2.AND.THKMX2(1,1).LT.1.0)THEN
      DEPTH=THKMX2(1,1)+THKMX2(2,1)
      NOMATL=1
      NIPTS=2
      DO 450 J=1,6
       THKMX1(1,J)=VOLDSN(1,J)
450   CONTINUE
      THKMX1(1,1)=DEPTH
      DEPMX1(2,1)=DEPTH
      DEPMX1(1,2)=AVSTP
      DEPMX1(2,2)=AVBOTTP
      END IF
C
      MRSN=DFG+DELROS
      WENS=DFG*VNEWSN(1,6)
      WEOS=DELROS*VOLDSN(1,6)
      MRWE=WENS+WEOS
      IF(MRSN.LT.0.0)THEN
      MRSN=0.0
      END IF
      IF(MRWE.LT.0.0)THEN
      MRWE=0.0
      END IF
C***********************************************************************
```

VARIABLE DEFINITIONS: SNOMO

(1) MAIN PROGRAM

AIRTP	Air temperature, °C.
AVABSR	Mean daily shortwave radiation absorbed at the surface, $MJm^{-2}day^{-1}$.
AVATER	Mean daily shortwave radiation absorbed at the surface, $MJm^{-2}day^{-1}$.
AVBTTP	Mean daily temperature at the base of the snowpack, °C.
AVDTER	Mean daily evaporative heat flux, $MJm^{-2}day^{-1}$.
AVGBR	Mean daily reflected longwave radiation, $MJm^{-2}day^{-1}$.
AVHTER	Mean daily sensible heat flux, $MJm^{-2}day^{-1}$.
AVSOL	Mean daily incoming shortwave radiation, $MJm^{-2}day^{-1}$.
AVSTP	Mean snow temperature, °C.
BOTTP	Temperature at the base of the snowpack, °C.
CELL	Identification number of the computational cell being modelled.
CRITDP	Critical snowdepth, 5cm.
DATMX	Matrix holding TSTM output values for manipulation.
DAY	Julian date of day being modelled.
DAY1	Julian date of SNOMO initiation.
DDATE	Julian date of day being modelled.
DELQS	ΔQ_s, snowpack internal energy change, $MJm^{-2}day^{-1}$.
DENSN	Density of snow, gcm^{-3}.
DENW	Density of water, gcm^{-3}.
DEPMX1	Depth matrix for a 1-layer pack.
DEPMX2	Depth matrix for a 2-layer pack.
DEPTH	Snowpack depth, cm.
DEPTH1	Used in calculation of depth when converting 'new snow' to 'old snow'.
DUDT	dU/dt, part of the snowpack energy-budget equation (equivalent to ΔQ_s), redundant.

ENAVM Energy availiable for melt, ΔQ_m, calculated using energy totals, $MJm^{-2}day^{-1}$.

GTERM Ground heat flux, $calcm^{-2}min^{-1}$.

HCAPSN Heat capacity of snow, $kJkg^{-1} \cdot C^{-1}$.

HCAPW Heat capacity of water, $kJkg^{-1} \cdot C^{-1}$.

ILAPSE Determines which elevation data file is used to modify the air temperatures with lapse rate.

IRAIN Indicates occurence of rain-on-snow. If irain=0 then no rain-on-snow occured, if irain=1 rain-on-snow occured.

ISNOW Indicates if snowed on the previous day, isnow=0, no snowfall on previous day, isnow>0, snowfall on previous day.

IVEG Determines whether VEGIE is activated or not and which vegetation input file is used.

K1 Count of the number of days modelled, ie. the number of times the 'do 5001' loop is used.

K2 K2=0 indicates that SNOMO modelled soil in the previous iteration or that SNOMO is not modelling the first iteration. K2=1 indicates that that SNOMO modelled snow in the previous iteration or that it is the first iteration.

K3 K3=0, indicates soil modelled in previous iteration, K3=1, indicates snow modelled in previous iteration.

K25 Count of the days elapsed since the last snowfall.

K30 Indicator to facilitate the calculation of xsntp, in the melt calculations.

KELVIN Air temperature converted to degrees kelvin.

KONTRL Count of the number of days modelled.

LHEATF Latent heat of fusion, $MJkg^{-1}$.

MRSN Meltrate, cm snow.day^{-1}

MRWE Meltrate, mm snow water equivalent.day^{-1}.

NETRAD Net radiation, $m^{-2}day^{-1}$.

NIPTS	The number of times the output time print frequency is divisible by the time steps, used to determine when to print output.
NKONT	Used with KONTROL to terminate SNOMO.
NOMATL	The number of material layers used in solving the heat flow.
PPTN	Precipitation, mm water.
PTERM	Heat input to pack by rain-on-snow, $MJm^{-2}day^{-1}$.
RH	Relative humidity, %.
SNDP1	Initial snowdepth, cm
SNPPTN	Precipitation amount, cm snow.
SNVOL	area x depth, m^{-3}.
SOILDP	depth of soil profile at the base of the snowpack, cm.
SOILTP	Soil temperature at depth, taken at soildp, °C.
SPHTI	Specific heat of ice, $2.10x10^3$ $Jkg^{-1} \cdot K^{-1}$.
SPHTW	Specific heat of water, $4.18x10^3$ $Jkg^{-1} \cdot K^{-1}$.
SSOLTP	Surface soil temperature, °C.
STP	Surface temperature, °C.
TABSOR	Total daily shortwave radiation absorbed at the surface, $MJm^{-2}day^{-1}$.
TATERM	Total daily incoming longwave radiation, $MJm^{-2}day^{-1}$.
TDTERM	Total daily evaporative heat flux, $MJm^{-2}day^{-1}$.
TGBR	Total daily reflected radiation, $MJm^{-2}day^{-1}$.
THKMX1	Thickness matrix for a 1-layer pack.
THKMX2	Thickness matrix for a 2-layer pack.
THTERM	Total daily sensible heat flux, $MJm^{-2}day^{-1}$.
TIME2	Daily observation time, used to aid the sequential reading of the daily observation time.
TMAX	Lapse rate alteration of the maximum daily air temperature.
TMIN	Lapse rate alteration of the minimum daily air temperature.
TSOL	Total daily incoming solar radiation, $MJm^{-2}day^{-1}$.

VNEWSN	Vector holding new snow values of thermal diffusivity, heat conductivity, emissivity, albedo and density.
VOLDSN	Vector holding old snow values of thermal diffusivity, heat conductivity, emissivity, albedo and density.
VSOIL	Vector holding soil values of thermal diffusivity, heat conductivity, emissivity, albedo and density (redundant).
WE1	Used in the calculation of depth when converting 'new snow' to 'old snow', cm.
XXX(J,8)	Julian date.
XXX(J,1)	Observation time.
YEAR	Year of the simulation data.
YYY(J,1)	Minimum air temperature, °C, table 1.
YYY(J,2)	Relative humidity, %, table 2
YYY(J,3)	Cloud cover, 0-1, table 3.
YYY(J,6)	Wind speed, ms^{-1}, table 6.
YYY(J,7)	Precipitation, mm water.
YYY(J,9)	Maximum air temperature, °C.

(2) TSTM

AB	Mugge-Möller absorption function.
ACL(8)	Coefficient, a, dependent on cloud type, used in the calculation of CTF.
ALPH(IX)	Thermal diffusivity of layer IX, $cm^{-2}min^{-1}$.
AO	Atmospheric albedo for Rayleigh scattering.
APRM	$FACTE*TEMP^3$, $calcm^{-2}min^{-1}\cdot C$.
B	Heat conductivity of surface, $calcm^{-2}min^{-1}\cdot C$.
BBB(J,I)	Y intercept of linear equation, used for table interpolation.
BC	Constant used in the calculation of water vapour pressure.
BCT(8)	Coefficient, b, dependent on cloud type, used in the calculation of CTF.
BEP	Bottom boundary thermal IR emissivity.

BK	Bottom surface geometric shape, fraction (0.0-1.0)
BPRM	Heat conductivity of bottom boundary layer.
BTERM	Energy contributed by insolation after adjustment using surface absorptivity, calcm^{-2}min^{-1}.
CC	CLOUD * CLOUD.
COE1	Coefficient used in the calculation of HTERM, DTERM, EF and DTERM, set according to Richardson's Number.
COE2	Coefficient used in the calculation of HTERM, DTERM, EF and DTERM, set according to Richarson's Number.
COEF	Part of calculation of interface values.
CLR(8)	Coefficient dependent on cloud type, used in the calculation of incoming longwave radiation.
CLOUD	Cloud cover, fraction (0.1-1.0).
CP	Specific heat of dry air at constant pressure.
CTEMA	Air temperature in degrees kelvin, used in calculation of evaporative heat flux.
CTF	Cloud adjustment factor.
DAY	Julian day used in solving insolation.
DCOEF	Part of calculation of interface values.
DDDT	dT/dTg, part of upper boundary calculation.
DECL	Solar declination angle.
DELT	Time step in hours.
DEPTH(IY)	Matrix holding layer depths.
DEPTH(450)	Depth of snow or soil profile.
DOWNIR	Incoming longwave radiation, calcm^{-2}min^{-1}.
DPRM	Heat flux, calcm^{-2}min^{-1}, at bottom boundary or temperature in rankines at bottom boundary.
DPRM0	Temperature of bottom material, °C, used when LFLUX=0.
DPRM1	Heat flux of beneath bottom material, calcm^{-2}min^{-1}, used when LFLUXY not equal 0.
DTERM	Energy flux due to evaporation.
EA	Water vapour pressure of the air.
ELF	Latitude, radians.

EPSN	Emissivity of surface material.
ES	Water vapour pressure of the surface.
ESAT(T)	Saturated vapour pressure at temperature T.
E(T)	Vapour pressure at temperature T.
F2	Part of the calculation of bottom boundary values.
FACTA	SIGMA*EPSN
FACTD	FACTD=SIGMA*BK*BEP*TR**4, used in bottom boundary clculation when there is airspace beneath the bottom layer.
FACTE	FACTE=SIGMA*BK*BEP, used in bottom boundary calculation when there is airspace beneath the bottom layer.
FACTH	FACTH=(1000.0/PRESS)**0.286, used in solving convection term (HTERM).
FK(IX)	Heat conductivity of layer IX, calmin^{-1}cm^{-1}·K^{-1}.
FMM(J,I)	Slope of linear equation, used for table interpolation.
G	Acceleration due to gravity.
GTERM	Ground heat flux, calcm^{-2}min^{-1}.
HEADER	72 character input variable used to print comments on output (not utilised in SNOMO).
HTERM	Energy loss or gain due to convection, calcm^{-2}min^{-1}.
IEFSWT	Switch, when =0 will print output only at specified time, if not =0 will print output at every iteration.
IEOF	Set from 0 to 1 when an EOF is encountered, used to terminate program.
III	Count of number of interval iterations in calculation of upper boundary values.
IMATL	Backward counter of layers, starting with the number of layers.
INTR(IX)	Beginning sub-layer depth number for layer number IX.
IPRNT	Backward counter SET+NPRNT. When =1 output is printed.
ITER	Iteration counter used in finite difference calculation of heat flow equation.
ITIME	Backward counter initialize as total time steps in hour.
IX	Layer number starting with top layer.
IY	Sub-layer depth number.

JMAX	The total number of sub-layers.
K10	Count of the number of internal iterations of TSTM, in order to calculate the daily means of the TSTM calcuated energy-budget and temperature variables.
KSQ	von Karman's constant squared.
KTEMPA	Air temperature, degrees kelvin.
KTEMPG	Surface temperature, degrees kelvin.
LAYERS	Count of the profile layers.
LAT	Latitude used in solving insolation.
LFLUXY	Input bottom boundary data control switch. If =0, there is no heat flux through bottom of material, if negative there is no air space beneath bottom material, if positive there is air space beneath bottom material.
LN	Dummy variable to read line number from input file.
M	Secant of solar zenith angle, radians.
MAX(J)	Number of input table values used in table interpolation module.
NCLOUD	Cloud type index number (1-9) used in solving insolation, IR emission.
NETRAD	Net radiation, $MJm^{-2}day^{-1}$.
NIT	Number of iterations used in heat flow calculations.
NKONT	Used with KONTRL to terminate SNOMO.
NTABL	Table number.
NX(IX)	NX(IX)=THK(IX)/SFRQ(IX), number of sublayer of each layer.
OUTCD	Output manipulation variable.
PI	3.141593
PRESS	Atmospheric pressure, mb, used in solving insolation.
PTYME	Beginning time of output=total number of hours minus 24, used in print output module 2.
QSAT(T)	Saturated specific humidity at temperature T.
Q(T)	Specific humidity at temperature T.

REP	Emissivity beneath airspace.
RHOA	Air density, calculated as part of sensible heat calculation.
RHOC(IX)	FK(IX)/ALPH(IX), calcm^{-2}$\cdot$K^{-1}.
RI	Richardson's Number, index used in solving HTERM, DTERM, HTER, EF.
RK	Surface beneath airspace geometric shape, fraction (0.0-1.0).
RR(IX)	RR(IX)=DELT/SFRQ**2, part of heat flow equation.
SAZ	Solar azimuth, radians.
SCF	Used in calculation of sensible heat flux, determined by the Richardson number.
SFRQ(IX)	Vertical grid spacing in cm in each layer IX, cm^{2}m^{-1}.
SICF	Insolation adjustment due to zenith angle, surface slope and surface aspect angle.
SIGMA	Stefan-Boltzman constant, 8.12e-11.
SLOPE	Surface slope, degrees, with horizontal =0 degrees, used in solving insolation.
SMALLA	Absorbtivity of surface material.
SPEED	Wind speed, cmsec^{-1}.
STABN	Numerical stability parameter, ≤0.5 for numerical stability.
STOR(1,IY)	Estimate sub-layer temperature, degree rankine.
STOR(2,IY)	FK, heat conductivity of sub-layer IY, calmin^{-1}cm^{-1}$\cdot$K^{-1}.
STOR(3,IY)	RHOC, FK/ALPH, calcm^{-2}$\cdot$K^{-1}.
STOR(4,IY)	Constant dimensionless.
STOR(5,IY)	Initial snow temperature, degree rankine, of initial snow profile.
STOR(6,IY)	Same as STOR(2,IY).
STOR(7,IY)	Same as STOR(3,IY).
SUMC	Count of daily energy totals.
SUN	Calculated insolation value.
SURFAC	Surface azimuth, degrees, with south =0, west =+90 and east =-90 degrees, used in solving insolation.
T	Same as TIME.
TA	Air temperature, degrees rankine.
TAC	Air temperature, °C.
TAK	Air temperature, °K.
TAL	Constant used in the calculation of WATER.

TB	Thermal conductivity of bottom material, calcm^{-2}·C^{-1}min^{-1}.
TD	Dew point temperature used in the calculation of WATER.
TEML	Surface temperature of material, degrees rankine.
TEMR	Bottom layer temperature of material in degrees rankine.
TFRQ	Time step in minutes used in solving heat flow.
THK(IX)	Layer thickness, in cm of layer IX.
TIME	Time in hours which material temperatures are estimated.
TIMER	Sun's hour angle, radians.
TITLE	Surface temperature, °C.
TOTTIM	Total number of 24 hour repetitions used in solving heat flow.
TPRNT	Output time print frequency, minutes.
TR	Temperature of airspace beneathbottom material.
TSK	Material sub-layer temperature, °K.
TYME	Time in hours, used in insolation calculation.
WATER	The amount of precipitable water, mm, used in solving insolation.
WET	Moisture content of surface material.
XXX(J,1)	Time in hours for table 1 (air temperature).
XXX(J,2)	Time in hours for table 2 (relative humidity).
XXX(J,3)	Time in hours for table 3 (amount of cloud cover).
XXX(J,4)	Time in hours for table 4 (solar insolation).
XXX(J,5)	Depth, cm, for table 5 (temperature profile) initial temperature profile, °C.
YYY(J,4)	Insolation, calcm^{-2}min^{-1}, if 0.0 at 1200 hours, insolation values will be calculated, table 4.
Z	Solar zenith angle.
ZA	Shelter height, cm.
ZASH	Shelter height, cm.
ZZA	Surface temperature of material, degree rankine.
ZZB	Bottom layer temperature of material in degree rankine.

(3) VEGIE

ATERM	Atmospheric IR emission, cal $cm^{-2}min^{-1}$.
ATF(1)	Part of the root-finding algorithm.
ATF(2)	Part of the root-finding algorithm.
BINT	Part of the root-finding algorithm.
CH0	Dimensionless heat or moisture transfer coefficient applicable to the top of a dense canopy.
CHH	Dimensionless heat or moisture transfer coefficient applicable to the top of a dense canopy.
CHG	Heat transfer coefficient equation interpolated between ground with no cover, CH0 and complete cover, CHH.
CP	Specific heat of dry air at constant pressure.
DELTMP	Incremental temperature for the root-finding algorithm.
DTHETA	DTHETA=(TA-TF)*FACTH/ZA, used in the calculation of the Richardson Number.
DU	Used in the calculation of the Richardson Number.
E(T)	Vapour pressure at temperature T.
EF	Latent heat loss to the atmosphere for the foliage.
EFF	Effective temperature.
ELG	Latent heat loss to the atmosphere at the ground surface.
EP1	Part of the calculation of the energy budget for foliage.
EPF	Emissivity of foliage.
EPSN	Emissivity of ground (snowpack) surface.
ESAT(T)	Saturated vapour pressure at temperature T.
EX	Coefficient used in the calculation of HTERM, DTERM, HTER and EF, set according to Richardson's Number.
FACTH	Potential temperature.
FEB(1)	Part of the root-finding algorithm.
FEB(2)	Part of the root-finding algorithm.

FENB Energy-budget of the ground and foliage surfaces respectively.

FK(IX) Heat conductivity of ground (snowpack).

FOLA Absorptivity of the foliage layer (1-albedo).

FOLGB Foliage thermal IR emittance, calcm^{-2}min^{-1}.

G Acceleration due to gravity.

GRNDGB Ground thermal IR emittance, calcm^{-2}min^{-1}.

HFOL Foliage height, cm.

HSF Convective energy flux across the foliage surface.

HSG Convective energy flux across the ground (snowpack) surface.

HTER Part of the calculation of HSF.

QAF Specific humidity of air within the foliage layer.

QF Specific humidity of the air at foliage height.

QG Specific humidity of the ground (snowpack) surface.

QSAT(T) Saturated specific humidity at temperature T.

NDEX Count of the number of times the energy-budget for the ground or the foliage was calculated.

RA Atmospheric resistance.

RC Canopy resistance to water vapour diffusion

RDF Fraction of potential evaporation rate from foliage.

REFRAD Surface related radiation, calcm^{-2}min^{-1}.

RHOAF Density of air near ground surface.

RHOAG Density of air near the ground surface.

RI Richardson Number.

RLD Downward longwave flux over ground (snowpack) surface.

RLU Upward directed longwave flux radiated from ground (snowpack) surface.

RS Stomatal resistance.

SFRQ(IX) Distance of first grid point below the surface.

SG Incoming solar radiation reaching the ground (snowpack).

SHRW	Amount of shortwave radiation absorbed by foliage.
SIGF	Foliage cover fraction.
SIGMA	Stefan-Boltzmann constant.
SLOPE1	Part of the root-finding algorithm.
SMALLA	Ground (snowpack) surface absorptivity.
SOL	Calculated solar insolation reaching the top of the foliage layer.
STATE	Arbitrary multiplier (STATE>0) of RS used to account for sencesence, stress etc.
SURFGB	Surface (foliage + ground surface) thermal IR emittance, calcm^{-2}min^{-1}.
T1	Temperature at first grid point below surface, distance SRFQ(IX), in TSTM heat transfer algorithm.
TA	Air temperature.
TEFF	Mean effective temperature.
TEFFR	TEFF with reflection incorporated.
TEML	Ground (snowpack) surface temperature.
TF	Foliage temperature.
TF0	Part of the root-finding algorithm.
TF4	Part of the calculation of FENB.
TG4	Part of the calculation of FENB.
THETAV	Used in the calculation of Richardson's Number.
UA	Wind speed.
UAF	Wind speed of air in the foliage layer.
WET	Moisture content of ground (snowpack) surface.
XL1	L=f(T_a), used in the calculation of the latent heat of evaporation, a function of air temperature.
XLNGW	Part of the foliage energy-budget calculation.
Z0	Roughness length.
ZA	Instrument height above ground (snowpack).
ZDSP	Zero displacement height.

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